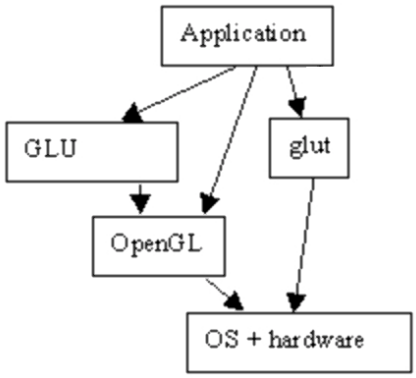
Open GL

A Crash Course

Part 1

What is OpenGL?

- Hardware independent graphics API (but support 3-D hardware)
- Geometric primitives (e.g. 3-D polygons, transforms, materials, rather than pixels)
- Includes GLU (higher level definitions for transforms, object, etc.)
- Platform independent (e.g. no windowing or user interface support)
- Doesn't generally include GLUT (windowing and user I/O)



- State machine (e.g. transforms, materials, lighting, shading model, line patterns, colors, normals, shading model)

Typical Program Structure:

Main:

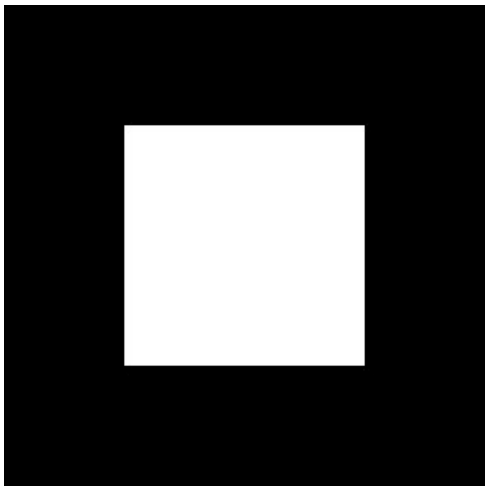
- Initialize Windows/Buffers (GLUT)
- Setup event handlers
- Set some initial GL states
- Store display lists
- Loop
  - Check for events
  - If window event, adjust view port, redraw
  - If user I/O event, adjust something, redraw

Redraw:

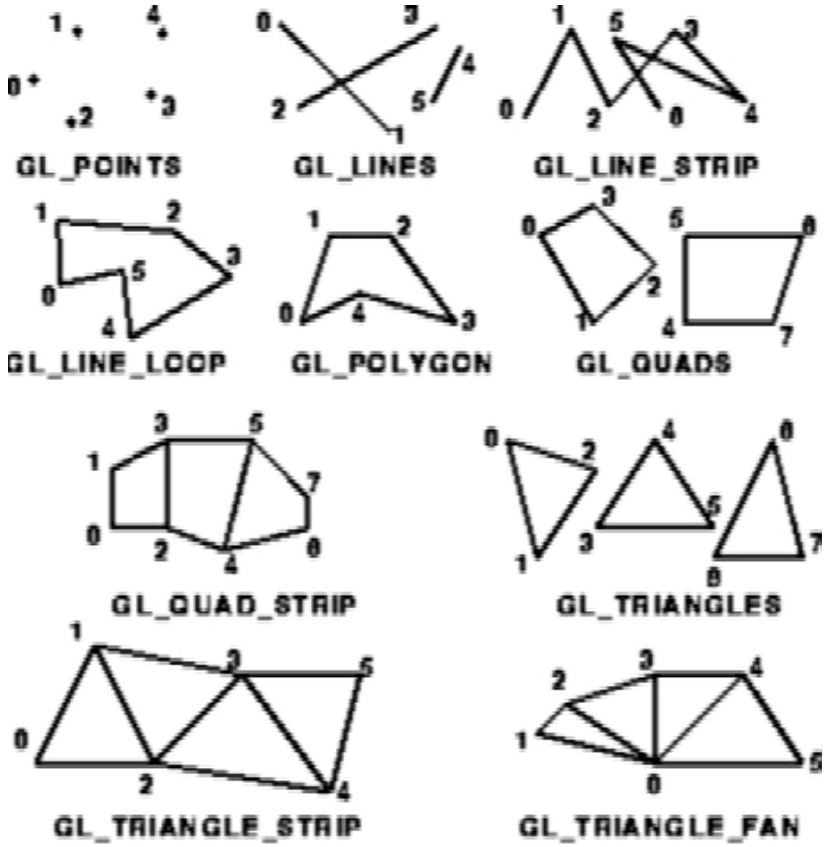
- Clear screen
- Change some states
- Render some graphics
- Change some more states
- Render some more graphics
- …and so on

Code Fragment:

```
main() {
   //Init windows/buffers
   //Enter main loop
}
redraw() {
   glClearColor(0.0,0.0,0.0,0.0);
   glClear(GL_COLORBUFFER_BIT);
   glColor3f(1.0,1.0,1.0);
   glOrtho(0.,1.,0.,1.,-1.,1.);
   glBegin(GL_POLYGON);
      glVertex3f(0.25,0.25,0.);
      glVertex3f(0.75,0.25,0.);
      glVertex3f(0.75,0.75,0.);
      glVertex3f(0.25,0.75,0.);
   glEnd();
   glFlush();
}
```



Primitive Types:

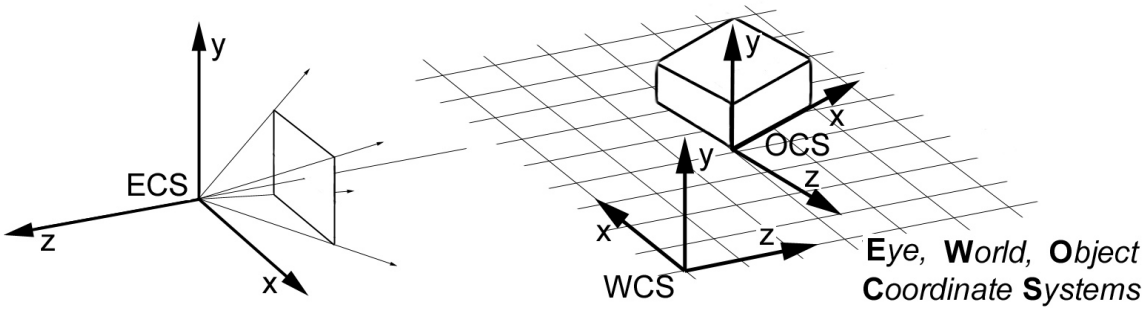


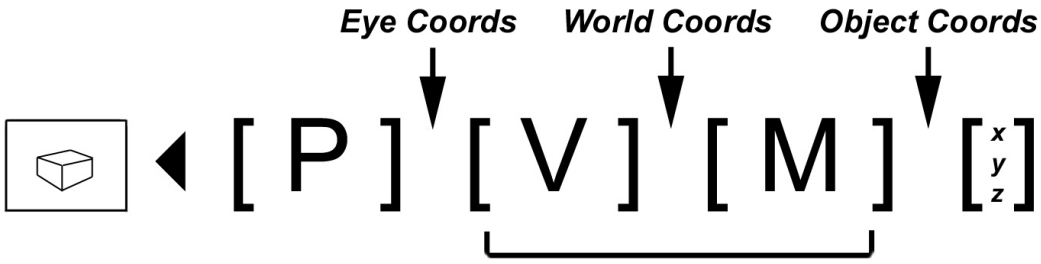

```
GLfloat p1[3] = {0,0,1};
GLfloat p2[3] = {1,0,1};
GLfloat p3[3] = {1,1,1};
GLfloat p4[3] = {0,1,1};

glBegin(GL_TRIANGLE_FAN);
   glVertex3fv(p1);
   glVertex3fv(p2);
   glVertex3fv(p3);
   glVertex3fv(p4);
glEnd();
```

Random Notes About Primitives:

- Syntax: glVertex{234}{sifd}[v]()
- GL assumes polygons are convex
- GL assumes polygons are planar
- Subdivide non-planar polygons into triangles
- Specify polygons in CCW order!

Coordinate Systems and Matrices:





Modeling Transform	`glTranslatef()`
	`glRotatef()`
	`glScalef()`

Viewing Transform	`gluLookAt()`

Projection Transform	`glFrustum()`
	`gluPerspective()`
	`glOrtho()`

Viewport Transform	`glViewport()`

Utilities	`glMatrixMode()`
	`glLoadIdentity()`
	`glMultMatrix()`
	`glPushMatrix()`
	`glPopMatrix()`

Typical Matrix Use:

Projection:

- Initialize at start up
- Adjust it when the window is resized

Modelview Matrix:

Viewing:

- Projection matrix has fixed viewpoint (0,0,0)
- Initialize at startup to produce viewpoint
- Modify it when the viewpoint must change

Modeling:

- Push the matrix onto the stack
- Apply transforms to orient for object placement
- Draw an object
- Pop the matrix
- Repeat…

In general, leave the Modelview matrix as you found it after drawing something.

Some State Management:

Basic Global States:

```
glEnable(),glDisable()
```

such as `GL_BLEND, GL_DEPTH_TEST, GL_FOG, GL_LIGHTING, GL_LINE_STIPPLE, GL_CULL_FACE` to enable the properties defined using the following types of commands.

Buffer Clearing:

```
glClearColor(0.0, 0.0, 0.0)
glClearDepth(1.0)
```

for calls to `glClear(GL_COLORBUFFER_BIT | GL_DEPTHBUFFER_BIT)`

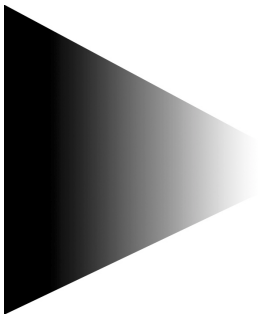
Color:

```
glColor3f(1.0, 1.0, 1.0)
glColor3fv(color_array)
glShadeModel(GL_SMOOTH)
glShadeModel(GL_FLAT)
```

Color (cont'd):

Can be defined per vertex. GL_SMOOTH will interpolate across polygon, but GL_FLAT picks one vertex and uses it's properties for whole polygon.

```
glBegin(GL_TRIANGLE);
    glColor3f(1.0, 1.0, 1.0)
    glVertex3fv(p1);
    glColor3f(0.0, 0.0, 0.0)
    glVertex3fv(p2);
    glVertex3fv(p3);
glEnd();
```



Point, Line and Polygon Details:

```
glPointSize(1.0)

glLineWidth(1.0)

glPolygonMode(GL_FRONT,GL_FILL)
glPolygonMode(GL_BACK,GL_LINE)
glFrontFace(GL_CCW)
glCullFace(GL_BACK)
```

Normals:

```
glNormal3f(1.0, 1.0, 1.0)
```

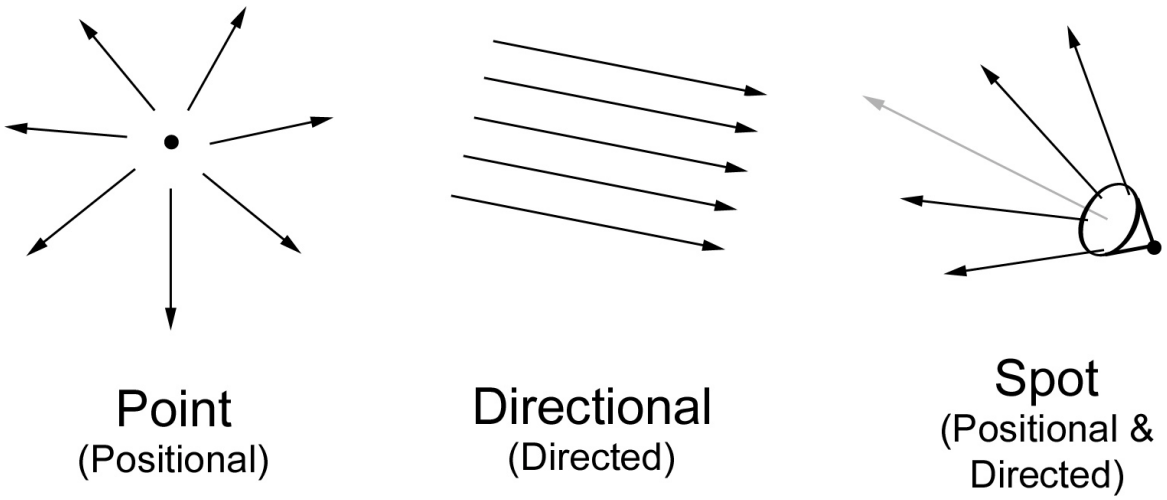
note: will be the normal for all vertices that follow it.

Lighting:

- Don’t use glColor3f()!!
- Let OpenGL calculate how each light strikes the surface and shades the primitive with the appropriate color
- Define object vertices with normals and material properties
- Define light sources that have color, position, direction, and some distribution

Three types of lights:

- Point source (light bulb)
- Directional light (sun at earth’s surface)
- Spot light (flashlight)



Three physical models (per type of light):

Ambient:

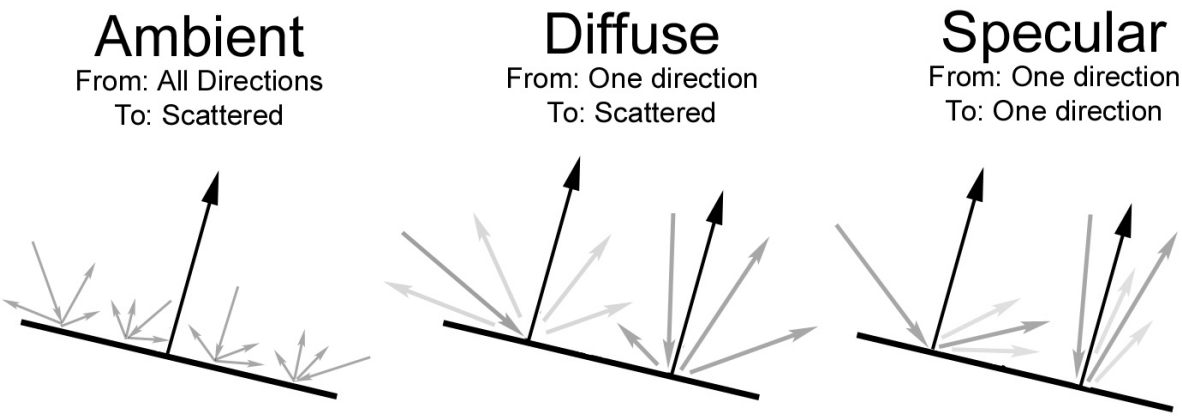
- Light so scattered that it appears to come from all directions
- Illuminates objects without regard to their orientation
- Bounces off surfaces in all directions

Diffuse:

- Light which comes from one direction
- Illuminates surfaces most strongly when perpendicular
- Bounces off surface in all directions

Specular:

- Light which comes from one direction
- Bounces off in one direction
- Effect depends on view point



Defining material properties:

- Can be defined per vertex
- State variable (like color)
- Different color for each physical model

Example:

```
glMaterialfv(GL_FRONT,GL_AMBIENT,&ambient[0])
glMaterialfv(GL_FRONT,GL_DIFFUSE,&diffuse[0])
glMaterialfv(GL_FRONT,GL_SPECULAR,&specular[0])
glMaterialf(GL_FRONT,GL_SHININESS,shininess)
glMaterialfv(GL_FRONT,GL_EMISSION,&emission[0])
```

Defining lighting model:

- Set the global ambient level
- Specify which side(s) of polygons to light
- Decide if view point is used in specular lighting calculations

Example:

```
glLightModeli(GL_LIGHT_MODEL_LOCL_VIEWER,GL_TRUE)
glLightModeli(GL_LIGHT_MODEL_TWO_SIDE,GL_FALSE)
glLightModelfv(GL_LIGHT_MODEL_AMBIET,&ambient[0])
```

Defining lights (common parameters):

- OpenGL guarantees at least 8 lights
- Different color for each physical model

```
glLightfv(GL_LIGHT0, GL_AMBIENT, &ambient[0]);
glLightfv(GL_LIGHT0, GL_DIFFUSE, &diffuse[0]);
glLightfv(GL_LIGHT0, GL_SPECULAR, &specular[0]);

glLightfv(GL_LIGHT0, GL_POSITION, x,y,z,w );
```

- `GL_POSITION` values define if a light is directional or positional (point source or spot light).
- If (x,y,z,w) has w=0 the light is directional, and (x,y,z) is its direction
- But if w=1 the light is positional and (x,y,z) is its position

Positional Lights (Point Source):

- `SPOT_CUTOFF` is the half angle of the spot light's cone. If it's 180, then we have a point source since we radiate all directions.

```
glLightf(GL_LIGHT0, GL_SPOT_CUTOFF, 180.0);
```

Positional Lights (Spot Light):

- If it's not 180, then an angle from 0-90 defines the cone of the spot light.

```
glLightf(GL_LIGHT0, GL_SPOT_CUTOFF, 30.0);
```

- These remaining properties control the direction, and fading from the center axis.

```
glLightfv(GL_LIGHT0,GL_SPOT_DIRECTION,&dir[0]);
glLightfv(GL_LIGHT0,GL_SPOT_EXPONENT,1.0);
```

Attenuation:

- Spot and point lights can be defined to attenuation with distance from their position.
- The factor is $1/(k_c + k_l d + k_q d^2)$
- It has no meaning for directional lights.

```
glLightfv(GL_LIGHT0,GL_CONSTANT_ATTENTUATION,Kc);
glLightfv(GL_LIGHT0,GL_LINEAR_ATTENTUATION,Kl);
glLightfv(GL_LIGHT0,GL_QUADRATIC_ATENTUATION,Kq);
```

Enabling:

- Lighting must be turned on.

```
glEnable(GL_LIGHTING);
glEnable(GL_LIGHT0);
```

Lighting Equation:

M – Material Color
L – Light Color

$$\text{Vertex Color} = M_{Emissive} + M_{Ambient} * L_{Global\ Ambient} + \Sigma\ \text{Attenuation} * \text{Spot Light Effect} * [M_{Ambient} * L_{Ambient} + M_{Diffuse} * L_{Diffuse} * \text{Angle Effect} + M_{Specular} * L_{Specular} * \text{Viewer Effect}]$$

Project Code:

```
#include <math.h>
#include <stdlib.h>
#include <stdio.h>
#include <GL/glut.h>

#ifndef min
#define min(a,b) (((a) <= (b)) ? (a) : (b))
#endif

#define KEY_SPACE  ' '
#define KEY_ESCAPE  '\033'
#define KEY_a 'a'
#define KEY_z 'z'
#define KEY_A 'A'
#define KEY_Z 'Z'

#define KEY_UPARROW  101
#define KEY_DOWNARROW  103
#define KEY_LEFTARROW  100
#define KEY_RIGHTARROW  102
#define KEY_PGUP  104
#define KEY_PGDN  105

#define MOVE_DIST 5.0
#define FOV 60.0
#define WIN_SIZE 500

//Far and near clip plane distances

#define FAR_Z 900.0
#define NEAR_Z 1.0

//Position and direction of the scene's spot light

#define L_P_X -50.0
#define L_P_Y 50.0
#define L_P_Z 50.0

#define L_D_X 80.0
#define L_D_Y -60.0
#define L_D_Z -80.0

////////////////////////////////////////////////////////////
GLuint listLight;                      //Handle to light's display list
GLuint listCube;                       //Handle to cube's display list

                                       //Position of observer
GLfloat positionX=0.0, positionY=0.0, positionZ=100.0;
////////////////////////////////////////////////////////////

void Init(void);                       //Location of glut init calls, etc.

void Keyboard(unsigned char,int,int);  //Normal key callback
void SpecialKeys(int,int,int);         //Special key callback
void Motion(int,int);                  //Mouse motion callback
void DepressedMotion(int,int);         //Mouse motion with button depressed
void Mouse(int,int,int,int);           //Mouse up or down button action
void MainMenu(int);                    //Main menu callback
void Idle(void);                       //Idle callback
void Draw(void);                       //Scene draw callback

void SetupLights(void);                //Generate light display list
void SetupCube(void);                  //Generate cube display list
```

```
void Reshape(int, int);                //Window resize callback
void Visible(int);                    //Window visibility callback
void DrawModeMenu(int);                //DrawMode menu callback


////////////////////////////////////////////////////////////////////

int main( int argc, char *argv[] )
{

  glutInit( &argc, argv );            //Let glut eat any command line options (i.e. none)

                                     //Specify a RGBA frame buffer, a back buffer, and z buffer
  glutInitDisplayMode( GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH);


   glutInitWindowSize(WIN_SIZE,WIN_SIZE);//Provide the window's width and height

   glutInitWindowPosition(0,0);        //Place it in the upper left corner


                                     //Create the window with the given title
  glutCreateWindow( "COS426: Assignment 2" );


  Init();                              //We use this to initialize our display lists, etc.


  glutMainLoop();                      //Pass event handling over to Glut.
                                     //Examine Init() to see what functions we pass
                                     // to the event call backs...
  return 0;
}

////////////////////////////////////////////////////////////////////

void Init( void )
{
  int submenu1;
  GLdouble aspect;

  glutDisplayFunc( Draw );            //Called when window is redrawn
  glutReshapeFunc( Reshape );          //Called when window is resized by the user
  glutKeyboardFunc( Keyboard );        //Called a alphanumeric or symbol is pressed
  glutSpecialFunc( SpecialKeys );      //Called when special keys (such as arrows) are pressed
  glutMouseFunc( Mouse );            //Called when a mouse button is clicked and when released
  glutMotionFunc( DepressedMotion ); //Called if mouse moves while a mouse button is depressed
  glutPassiveMotionFunc( Motion );    //Called if mouse moves (regardless of button status)
  glutVisibilityFunc( Visible );      //Called when the visible state of the window changes
  glutIdleFunc( Idle );         //When glut is not busy doing anything, it call this function.
                                     // this function migth be used to implement animation

                                    //Glut can provide a popup menu via a mouse button.
                                  //glutCreateMenu creates menus, glutAddMenuEntry add items to
                                  //menus, and glutAddSubMenu makes a menu into a submenu entry
                                       // of a higher level menu.

                                  //First we create the submenu, returning a identifier handle
                                     //for this menu. glutCreateMenu takes as an arguement the
                                       //call back function to use when an entry of the menu is
                                       //selected.
  submenu1 = glutCreateMenu( DrawModeMenu );
                                //glutAddMenuEntry defines entries to the lastest created menu.
                                       //The first arg is the entry label, and the second is an
                                       //integer passed to the menu's callback function
  glutAddMenuEntry( " Filled ", GL_FILL );
  glutAddMenuEntry( " Outline ", GL_LINE );
```

```
  glutCreateMenu( MainMenu );     //Now we create the top level menu and pass in the callback
                                      // function pointer
                                      //glutAddSubMenu add the previously defined submenu
                                      //with arguements being the submenu label and identifier
  glutAddSubMenu(" Polygon mode ", submenu1 );
                                      //We then add an entry as before
  glutAddMenuEntry( " Quit ", KEY_ESCAPE );
                                      //The function is bound to the right mouse button.
  glutAttachMenu( GLUT_RIGHT_BUTTON );

  glEnable(GL_DEPTH_TEST);            //Enable testing of the z buffer to properly render
                                      // occlusions
  glClearDepth(FAR_Z);            //Value used when clearing z buffer. We use far clip plane.
  glClearColor( 0.f, 0.f, 0.f, 0.f ); //Color to use when clearing frame buffer. We use black.

                                      //Set up the projection matrix
  glMatrixMode( GL_PROJECTION );      //Enter project matrix mode
  glLoadIdentity();                    //Reset to the identity matrix
                                     //Calculate the aspect ratio (1.0 in this initial case)
  aspect = (GLdouble) WIN_SIZE/ (GLdouble) WIN_SIZE;

                                      //For simplicity, we use the gluPerspective function to
                                      // set the projection matrix.  The arguements and the
                                      // field of view in degree, aspecct ratio, and the
                                      // distance of the near and far clipping planes
  gluPerspective(FOV,aspect,NEAR_Z,FAR_Z);

                                      //Now switch to modelview matrix mode and initialize the
                                      // state. Our projection  acts as if we view the world
                                      // from position (0,0,0), looking in the -z direction.
                                     //So, to place ourselves at position (x,y,z), we move the
                                      // whole world by a translation of (-x,-y,-z)
  glMatrixMode( GL_MODELVIEW );
  glLoadIdentity();
  glTranslatef(-positionX,-positionY,-positionZ);

                                      //To greatly enhance performance at drawing time, we can
                                      // precompile our calls to GL into display lists. Then,
                                      // at draw time, we call GL to display the lists.  By
                                      // precompiling our static objects into such lists, the
                                      // various GL calls to create the object are pre-stored
                                      // in GL's efficient internal reppresentation.

  SetupLights();                      //Store the scene's light into a list
   SetupCube();                        //Store the cube into a list



}

////////////////////////////////////////////////////////////////
// This is the keyboard event call back. Use it to implement
//  the control required to operate your scene.
////////////////////////////////////////////////////////////////

void Keyboard( unsigned char c, int x, int y )
{
  switch( c ){
  case KEY_ESCAPE:
    exit( 0 );
  break;

  case KEY_SPACE:

  break;

  case KEY_A:
```

```
  case KEY_a:

  break;

  case KEY_Z:
  case KEY_z:

  break;
  }
}
////////////////////////////////////////////////////////////////////
// This is the special keyboard event call back. Use it to implement
//  the control required to navigate/operate our scene.
//
//  Provided is a rudimentary movement system. You will modify this.
//
////////////////////////////////////////////////////////////////////

void SpecialKeys( int key, int x, int y )
{

  switch( key ){

  case KEY_UPARROW:
    positionZ-=MOVE_DIST;
  break;

  case KEY_DOWNARROW:
    positionZ+=MOVE_DIST;
  break;

  case KEY_LEFTARROW:
    positionX-=MOVE_DIST;
  break;

  case KEY_RIGHTARROW:
    positionX+=MOVE_DIST;
  break;

  case KEY_PGUP:
    positionY+=MOVE_DIST;
  break;

  case KEY_PGDN:
    positionY-=MOVE_DIST;
  break;
  }
                                      //Since we have moved the viewpoint, we reset the
                                      // modelview matrix to the new position
  glMatrixMode( GL_MODELVIEW );
  glLoadIdentity();
  glTranslatef(-positionX,-positionY,-positionZ);

                                      //Then we force glut to invoke our drawing callback
  glutPostRedisplay();
}

////////////////////////////////////////////////////////////////////
//
// If a mouse button is currently depressed, and the mouse moves
//  then this callback is invoked with the current position of the mouse
//
////////////////////////////////////////////////////////////////////

void DepressedMotion( int x, int y ){

}
```

```
//////////////////////////////////////////////////////////////////
//
// This callback is invoked with the current position of the mouse
//  anytime the mouse moves.
//
//////////////////////////////////////////////////////////////////

void Motion( int x, int y) {



}

//////////////////////////////////////////////////////////////////
//
// This callback is invoked whever the state of a mouse button
//  changes.  button specifies the button that changes state,
//  state specifies whether it was pressed or released, and
//  x,y is the current mouse position.
//
//////////////////////////////////////////////////////////////////

void Mouse( int button, int state, int x, int y )
{

  switch( button ){

  case GLUT_LEFT_BUTTON:
    if( state == GLUT_DOWN ){

    }
    else if( state == GLUT_UP ){

    }
  break;
  case GLUT_MIDDLE_BUTTON:
    if( state == GLUT_DOWN ){

    }
    else if( state == GLUT_UP ){

    }
  break;
  }

  //We could put the right button here, but its already bound to the menu

}
//////////////////////////////////////////////////////////////////
//
// This callback is invoked whever and entry of the drawmode sub
//  menu is selected.  entry will be the integer which we attached
//  to the chosen menu entry in the Init() function
//
//////////////////////////////////////////////////////////////////

void DrawModeMenu( int entry )
{
  glPolygonMode( GL_FRONT, entry );
  glPolygonMode( GL_BACK, entry );
  glutPostRedisplay();

}



//////////////////////////////////////////////////////////////////
```

```
//
// This callback is invoked whever and entry of the main
//  menu is selected.  entry will be the integer which we attached
//  to the chosen menu entry in the Init() function
//
//////////////////////////////////////////////////////////////////

void MainMenu( int entry )
{
  switch( entry ){

  case KEY_ESCAPE:
    exit( 0 );
  break;

  }
}
//////////////////////////////////////////////////////////////////
//
//  When glut is not busy doing anything, this call back is invoked.
//  This might be a good location to place code which modifies
//   your objects so to achieve animation.
//
//////////////////////////////////////////////////////////////////

void Idle( void )
{

  //Insert code too dynamically modify scene

  glutPostRedisplay();  //Redraw

}

//////////////////////////////////////////////////////////////////
//
//  This function, called within Init(), specifies a light
//   into a display list.  During Draw() we execute the list to
//   place the light into the scene.
//
//////////////////////////////////////////////////////////////////

void SetupLights(void){

                                    //Fist setup the light's properties
  GLfloat lm_ambient[]=  {0.5, 0.5, 0.5, 1.0};
  GLfloat l0_ambient[] = {0.2, 0.2, 0.2, 1.0};
  GLfloat l0_diffuse[] = {1.0, 1.0, 1.0, 1.0};
  GLfloat l0_specular[] ={1.0, 1.0, 1.0, 1.0};
  GLfloat l0_position[] ={L_P_X, L_P_Y, L_P_Z, 1.0};
  GLfloat l0_spotdir[] = {L_D_X, L_D_Y, L_D_Z};


  listLight=glGenLists(1);       //glGenList(n) requests integer handle to empty display list.
                                //If n>1, then the returned handle is the integer of the first
                                    // of n contiguous empty lists.

  glNewList(listLight,GL_COMPILE);    //glNewList(n,x) signifies that the following GL calls
                                 // be compiled into list n.  GL_COMPILE tells GL to store the
                                    // list.  Alternatively, we could simultaneously store and
                                    // execute (draw) the list.

                                    //Commands to generate the light follow.
  glLightModeli(GL_LIGHT_MODEL_LOCAL_VIEWER,GL_TRUE);
  glLightModelfv(GL_LIGHT_MODEL_AMBIENT,lm_ambient);
  glLightModeli(GL_LIGHT_MODEL_TWO_SIDE,GL_FALSE);

  glLightfv(GL_LIGHT0, GL_AMBIENT, l0_ambient);
```

```
  glLightfv(GL_LIGHT0, GL_DIFFUSE, l0_diffuse);
  glLightfv(GL_LIGHT0, GL_SPECULAR, l0_specular);
  glLightfv(GL_LIGHT0, GL_POSITION, l0_position);
  glLightfv(GL_LIGHT0, GL_SPOT_DIRECTION, l0_spotdir);

  glEnable(GL_LIGHTING);
  glEnable(GL_LIGHT0);

  glEndList();                        //glEndList stop compiling to the current list

}
////////////////////////////////////////////////////////////////////
//
//  This function, called within Init(), specifies a cube
//   into a display list.  During Draw() we execute the list to
//   place the cube into the scene.
//
////////////////////////////////////////////////////////////////////

void SetupCube(void){

  GLfloat mb_ambient[]= { 0.4, 0.4, 0.4, 1.0 };
  GLfloat mb_diffuse[]= { 0.6, 0.6, 0.6, 1.0 };
  GLfloat mb_specular[]= {0.3, 0.3, 0.3, 1.0 };
  GLfloat mb_shininess=  40.0;
  GLfloat mb_emission[]= { 0.0, 0.0, 0.0, 1.0 };

  listCube=glGenLists(1);            //Request handle to empty list

  glNewList(listCube,GL_COMPILE);    //Begin compiling the list

  glMaterialfv(GL_FRONT, GL_AMBIENT, mb_ambient);
  glMaterialfv(GL_FRONT, GL_DIFFUSE, mb_diffuse);
  glMaterialfv(GL_FRONT, GL_SPECULAR, mb_specular);
  glMaterialf( GL_FRONT, GL_SHININESS, mb_shininess);
  glMaterialfv(GL_FRONT, GL_EMISSION, mb_emission);

  glutSolidCube(10.0);

  glEndList();                        //End the list
}


////////////////////////////////////////////////////////////////////
//
//  This function, called by Glut when the scene is redrawn.
//  Since we have double buffering enabled, the scene is
//   actually rendered into an offscreen buffer.  When we
//   complete the redraw, we call gluSwapBuffers to exchange
//   the offscreen buffer with the current visible frame buffer.
//
////////////////////////////////////////////////////////////////////

void Draw( void )
{

                                    //First we empty out the off screen buffer

  glClear( GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT );

  glCallList(listLight);              //Then execute the light display list

  glPushMatrix();                      //Now draw the objects
    glTranslatef(-5,10,0);
    glRotatef( -35, 0, 1, 1 );
    glCallList(listCube);
  glPopMatrix();
```

```
  glPushMatrix();                      //Note that we can call the cube list
    glTranslatef(5,-5,-5);            // more than once to replicate it.
    glRotatef( -55, 1, 1, 0 );
    glCallList(listCube);
  glPopMatrix();

  glutSwapBuffers();                  //Exchange front and back buffers
}
//////////////////////////////////////////////////////////////////////
//
//  If the user resizes the window, the perspective transform maybe
//   inappropriate to the new aspect ration. To repair the distortion
//   we recalculate the projection matrix.
//
//  You shouldn't have to play with this...
//
//////////////////////////////////////////////////////////////////////


void Reshape( int width, int height )
{
    GLdouble aspect;
                                      // The user just changed the window size
  glViewport( 0, 0, width, height );  // We must respecify the projection to avoid distortion
  glMatrixMode( GL_PROJECTION );
  glLoadIdentity();
  aspect = (GLdouble) width  / (GLdouble) height;
  gluPerspective(FOV,aspect,NEAR_Z,FAR_Z);

  glMatrixMode( GL_MODELVIEW );        // Now return to modelview mode.

}

//////////////////////////////////////////////////////////////////////
//
//  If the visibility of the window changes (e.g. window is minimized
//    or un-minimized), then adjust the idle callback to avoid
//    drawing to and invisible viewport.
//
//  You shouldn't have to play with this...
//
//////////////////////////////////////////////////////////////////////
void Visible( int state )
{

  switch( state ){
  case GLUT_VISIBLE:
    glutIdleFunc( Idle );
    break;
  case GLUT_NOT_VISIBLE:
    glutIdleFunc( 0 );
    break;
  }
}
```