Animation Physics (Phys 23)
Lesson Plan

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Lesson: Ray Tracing and Shadows

Timeframe: Approximately 60 minutes

Materials needed: Copies of the worksheets, inexpensive straight edges (rulers) for drawing straight lines, and extra pencils for the students. Projection system for presenting powerpoint slides. System for answering quiz questions (clickers, flash cards, or just pencil & paper).

Objectives:

Basic:

1. List and explain the basic principles of ray tracing in computer graphics.

2. Distinguish various types of light sources, such as spot lights, point lights, etc..

3. Identify the different types of shadows and the situations in which they occur.

4. Identify diffuse and specular reflection of light by surfaces.

Advanced:

1. Apply the principles of ray tracing to predict the lighting of a scene.

2. Illustrate the types of shadows produced by various light sources.

3. Predict how surface properties affect the appearance (e.g., highlights).

Background: The course consists of primarily students in the visual arts and in this part of the class they are learning to use 3D computer graphics applications, such as Maya and Blender, to create scenes. These students often have difficulties understanding how to use different types of light sources (directional, point, spot, etc.) in rendered scenes so they resort to trial and error in selecting and positioning lights. This may create an acceptable image from one camera angle but it will not be suitable if the camera moves or the objects in the scene are animated.

Introduction to Lesson: During the week before the class the students will watch tutorial videos that explain ray tracing and describe the different types of light sources used in computer graphics. The videos also cover various types of shadows (cast, form, occlusion, etc.) and how they depend on the type of light source illuminating a scene. Students will also learn about standard physical models that describe how light reflects off the surfaces of objects. All of the videos are followed by a short (2 question) quiz; see Appendix A for sample questions. During the in-class group activity the students will apply what they've learned to predict what a scene will look like for a specified lighting situation (see Appendix B). Finally, as a post-class homework exercise they will use computer graphics software to reproduce the lighting in a photograph of a real object.

Procedure:

Pre-Class Individual Space Activities and Resources [90 minutes]:

Steps	Purpose	Estimated Time	Learning Objective
Step 1: Watch the video "Intro to Lighting" http://youtu.be/NALKrpyMovQ Following the video take a short (2 question) quiz on Canvas worth 2 points.	Introduce students to basic ray tracing as it applies to computer graphics.	20 min.	#1 (Basic)
Step 2: Watch the video "Lights & Shadows, Part 1" http://youtu.be/kudNuSRtMKw Following the video take a short (2 question) quiz on Canvas worth 2 points.	Explain the basic properties of shadows cast by the various light sources used in computer graphics.	20 min.	#2 & #3 (Basic)

Step 3: Watch the video "Lights & Shadows, Part 2" http://youtu.be/ZDGxIMBGqVs Following the video take a short (2 question) quiz on Canvas worth 2 points.	Explain how angle and distance between lights and objects affects form shadows and cast shadows.	20 min.	#2 & #3 (Basic)
Step 4: Watch the video "Diffuse & Specular Reflection" http://youtu.be/Is-7M4LXEDU Following the video take a short (2 question) quiz on Canvas worth 2 points.	Introduce students to physical models used for specular and diffuse reflection.	20 min.	#4 (Basic)
Step 5: Submit a single "Muddiest Point" question by Canvas worth 5 points. *All of the Steps above are due 24 hours before the In-Class Group Space meeting.*	Prerequisite for starting the discussion in the group space.	10 min.	All Basic LOs

In-Class Group Space Activities and Resources [60 minutes]:

Steps	Purpose	Estimated Time	Learning Objective
Step 1: Answer a selection of the "Muddiest Point" questions submitted before class.	Clear up any general confusion or misconceptions.	5 min.	All Basic LOs

Step 2: Short quiz (3-5 questions) conducted in the "Think, Pair, Share" format. Questions are similar to those in the quizzes taken on Canvas during the pre-class Individual Space activities. Optional: Collect and grade.	Review and reinforce the material introduced in the individual space.	10 min.	All Basic LOs
Step 3: Working in small (2-3 person) groups the students try to solve a simple lighting cas study. The challenge is to predict what a simple scene will look like when illuminated by a light source. Each team receives a worksheet with an image of the scene and they "color" in their prediction for the lighting. See Appendix B for details.	Have students apply the concepts they learned in the individual space to a practical case study.	10 min.	#1 & #2 (Advanced)
Step 4: The instructor shows the students what the rendered image should look like and discusses the key features. Students are given a chance to discuss and ask questions.	Allow students to self-assess their work and discuss it with peers.	5 min.	#1 & #2 (Advanced)
Step 5: Steps 3 and 4 are repeated for two more scenes, each of increasing complexity (e.g., locating highlights). Optional: For the last scene, before being shown the rendered image (Step 4) the student teams turn in their sketch for grading.	Reinforce the concepts by applying them to successively more difficult case studies.	30 min.	All Advanced LOs

Closure/Evaluation [5 minutes]:
Describe the upcoming homework assignment (see below and Appendix C) and discuss how it relates to the group space activities that were completed in class.

Analysis:
Students in this class are primarily majoring in the visual arts (animation, illustration, film, etc.) and they are accustomed to making sketches as part of their work. They tend to classify themselves as "visual learners" so whenever they have the opportunity to learn by put pencil to paper they consider that a big plus. The in-class group space activity is designed to allow students to apply the general concepts they learn in the pre-class individual space activities in a mode that they are comfortable working in, namely, sketching with pencil and paper. Computer graphics software is extremely powerful but also complex and confusing. Having the students first practice applying the concepts of ray tracing manually should make it easier for them to later apply them in the computer, which they do as the post-class individual space activity.

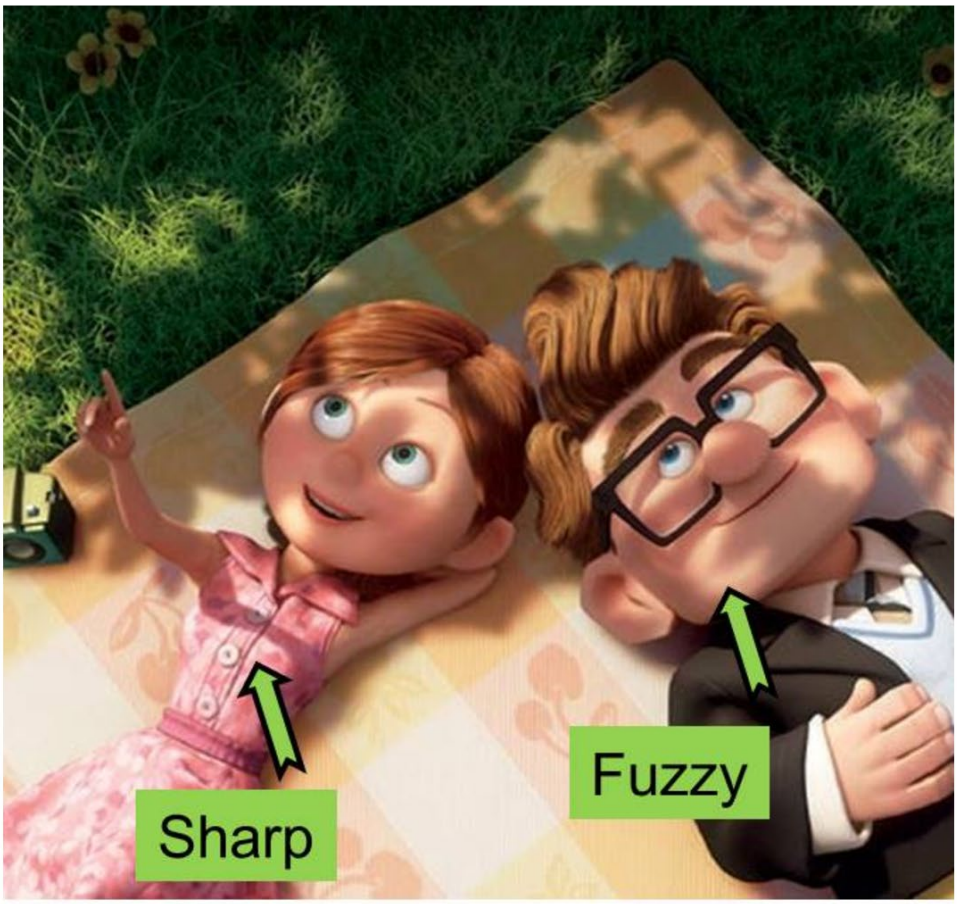
Post-Class Individual Space Activities:
Students will apply their knowledge of ray tracing and shadows in a homework assignment (see Appendix C). Specifically, they will be given a photograph of a simple object illuminated in a photography studio setting. Their assignment will be to use a professional computer graphics program, such as Autodesk Maya or Blender, to reproduce the lighting in their assigned photo. To achieve an acceptable image they will need to use several light sources of different types and for each light source the parameters (intensity, location direction angle, penumbra angle, etc.) will have to be adjusted. Besides getting the illumination on the object correct they will also have to match the shadows and the surface highlights in the photo. Note that in a previous homework assignment the students become familiarized with the software by creating a simple scene but using the default lighting.

Connections to Future Lesson Plan(s):
The topics that come next are color, refraction, scattering, and cinematic optics. For these topics an understanding of basic ray tracing and shadows is an essential foundation. The individual space activities (watching videos; doing quizzes; submitting "Muddiest Point" question) would be similar. The group space activities could also be similar however the small team challenge exercises would have to be tailored for each topic.

Appendix A
Sample Pre-class Quiz Questions

Question 2 1 pts

In the image below from Pixar's Up, Ellie's arm casts a sharp shadow while the leaves in the tree cast fuzzy shadows. Which of these is physically correct.



- The sharp shadow is correct; the shadows of the leaves should also be sharp since the Sun is a directional light source.
- The fuzzy shadows are correct and all the shadows should be similar since they're due to the same light source (the Sun).
- Both shadows are correct since the penumbra of a solar shadow increases the farther the object is from the ground.
- Both shadows are wrong; Ellie's arm should cast a fuzzy shadow while the leaves should cast sharp shadows.

Question 1 1 pts

When lighting is physically accurate, the intensity of light shining on a surface from a point light or spot light depends _____ .

- Only on the distance between the light source and the surface.
- Only on the angle between the light source and the surface.
- On both the distance and the angle between the light source and the surface.
- On neither the distance nor the angle between the light source and the surface; it only depends on the angle and distance to the viewer (or camera).

Question 2 1 pts

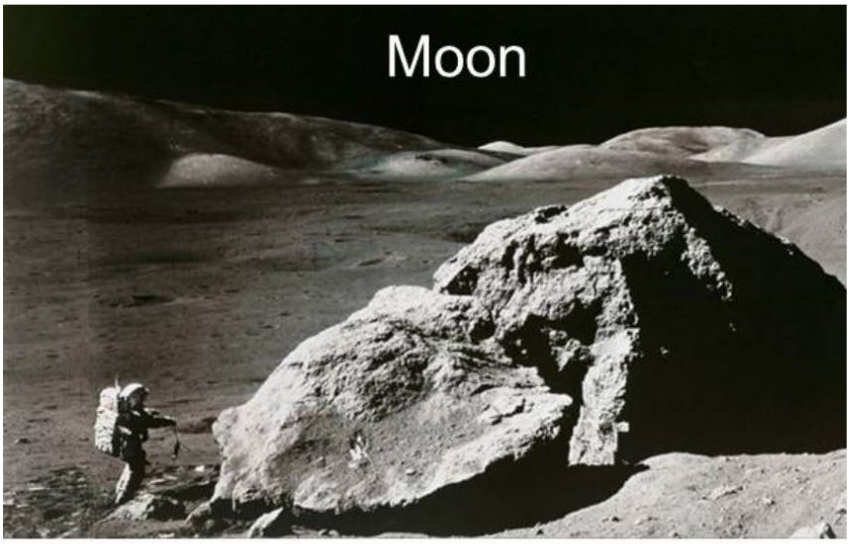
In his blog, the illustrator James Gourney writes, "Wherever two forms touch each other, or a form touches a floor, a dark line or accent results. You can see the effect by pressing your fingers together and looking at the little dark line where they touch. Not much light makes it to that point of contact. You'll also notice it gets darker in the inside corner of a room where the walls meet."

This effect occurs even in ambient lighting conditions. What is it called?

- Form shadows
- Fold shadows
- Accent shadows
- Rim shadows
- Occlusion shadows

Question 1 1 pts

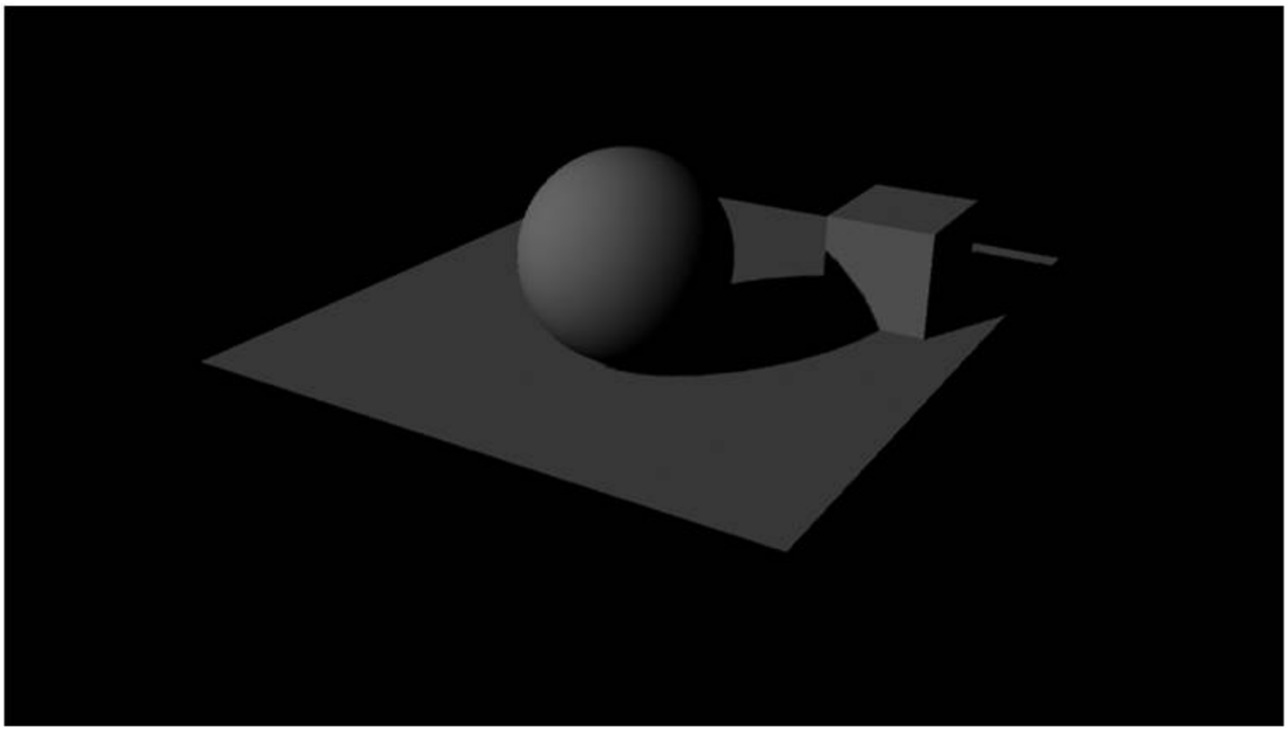
The two black-and-white photos below show a rocky, desolate landscape; one was taken on the moon and the other one on Earth. Which statement(s) below are correct (mark all that are correct)?



- [ ] The photo on the moon has a dark sky because it is night time.
- [ ] The shadows of the rocks on the moon appear very dark because the photo is underexposed.
- [ ] The shadows of the rocks on the Earth are not very dark because they are illuminated by the sky.
- [ ] On the moon the Sun is always directly overhead.

Question 2 1 pts

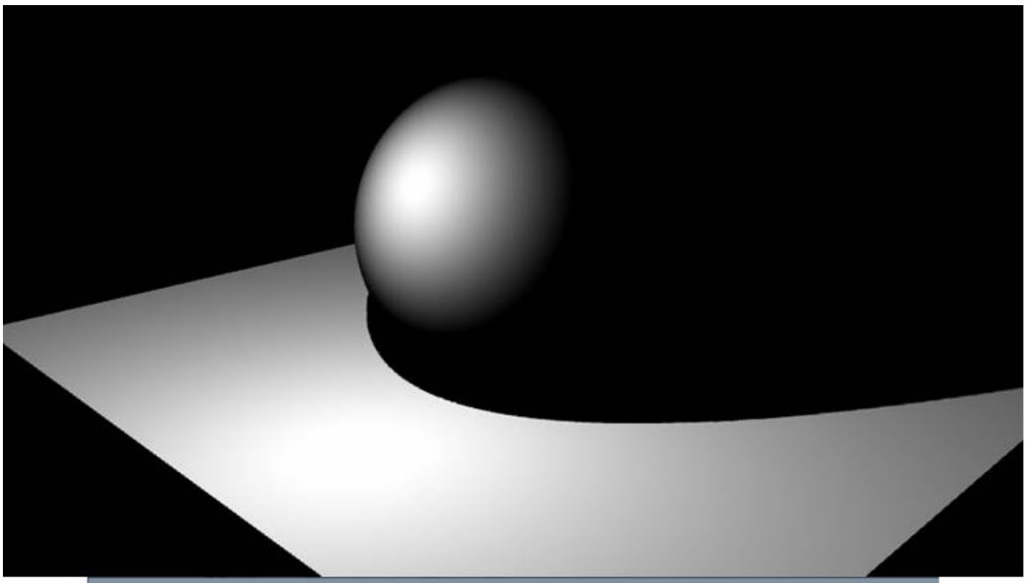
In the image below all the objects in the scene are Lambert diffuse surfaces illuminated by a directional light. If we move the camera to view the scene from another direction, which of the following statements will be true? Check all that apply.

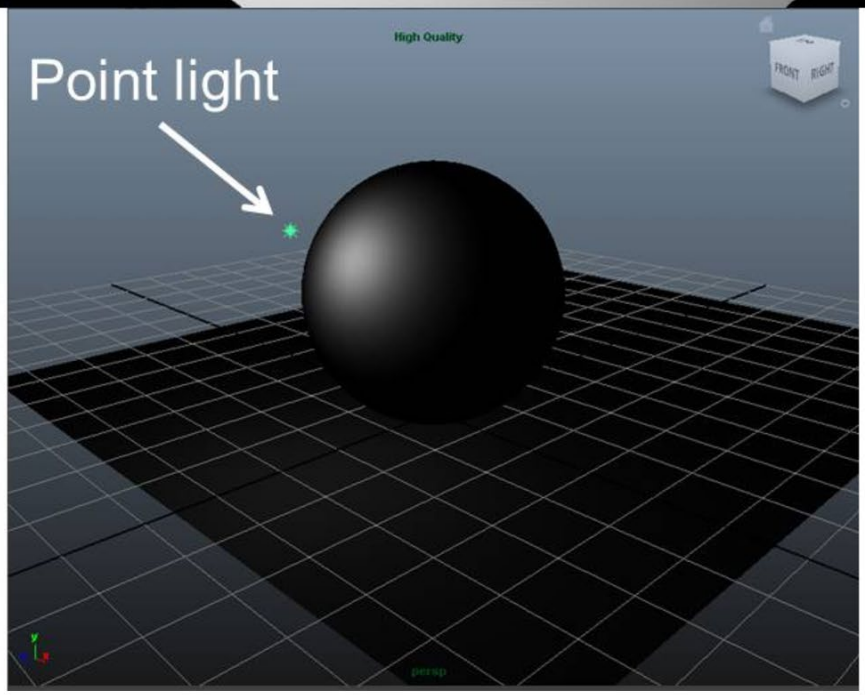


- [ ] The brightness of the floor will not change.
- [ ] The brightness of the top of the cube will not change.
- [ ] The form shadow on the sphere will not change.
- [ ] The brightness of the top of the cube will be the same as the floor.
- [ ] The cast shadows will not change.
- [ ] None of the above is correct.

Question 2 1 pts

The image below was created in Maya by positioning a point light near a sphere sitting on a flat plane. The lighting in this image is not physically realistic because _____. Check all that apply.





- [ ] The light on the sphere should extend all the way to the equator.
- [ ] The cast shadow on the floor is the wrong shape.
- [ ] The floor is too uniformly bright; it should be much darker towards the corners of the floor.
- [ ] The brightest spot on the floor should be much darker than the brightest spot on the sphere.

Appendix B
Group Space Activity

Students will receive worksheets similar to the one on the next two pages for the in-class group space activity. The purpose of the activity is for them to apply what they've learned about lighting, ray tracing, shadows, and surface reflection to predict what a simple scene will look like under basic illumination.

The rendering activity worksheet on the next page shows the wireframe for a sphere on a flat surface. The cone in the scene is a spotlight pointed towards the sphere. On the following page is same scene viewed from various perspectives; this will be printed on the back of the worksheet.

Students will work in small (2-3 person) groups to color in the wireframe image to predict what the render scene will look like under the illumination of the spotlight. Specifically, they should locate the edge of any cast shadows and the terminator for any form shadows. They will be encouraged to draw accurately by using rulers.

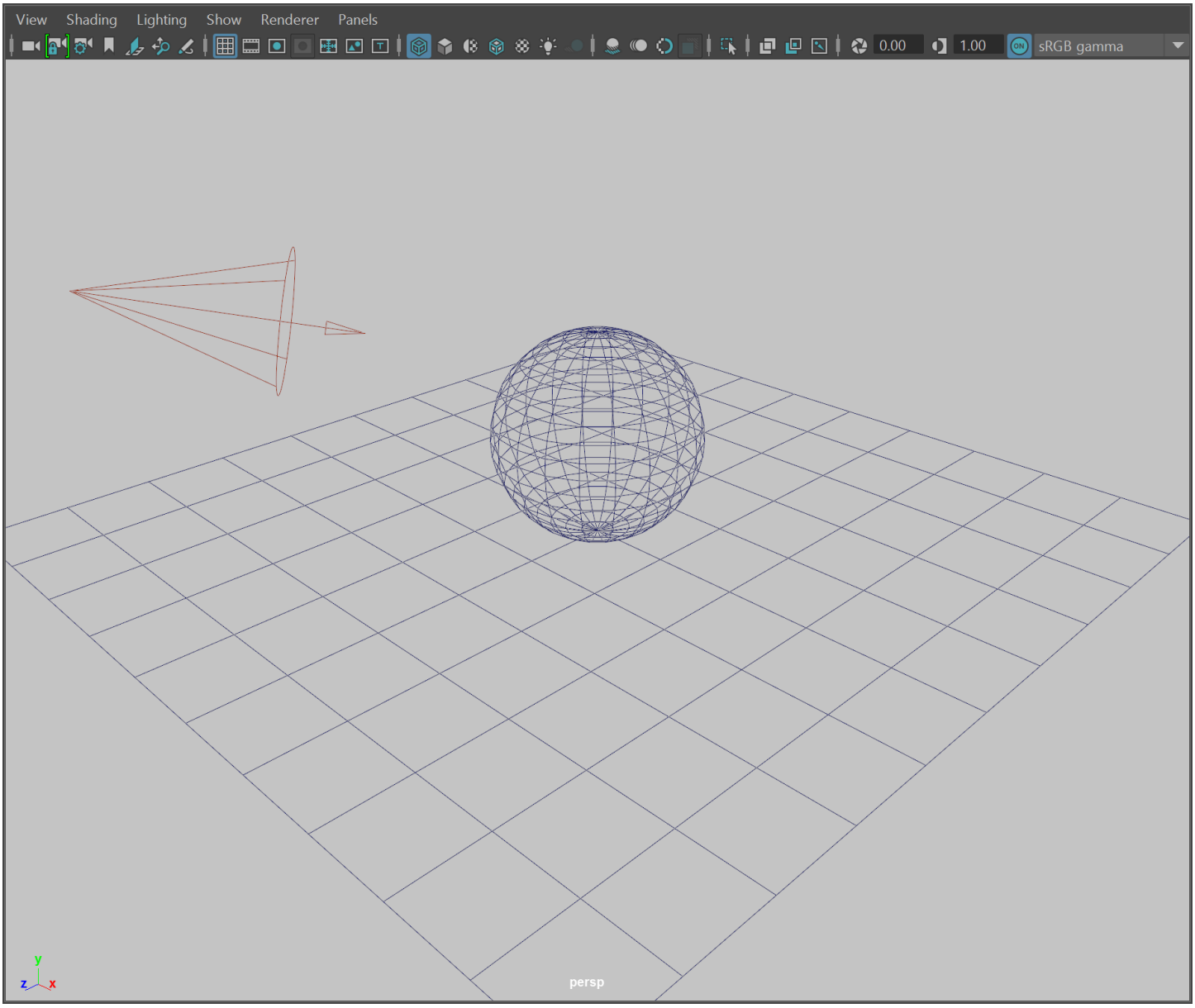
After about 10 minutes of drawing on their worksheet sheet the rendered image will be shown to the class. The instructor will point out various key features in the image that students should look for and check in their sketch.

This activity is then repeated for two more times, each time with a more complicated scene. Optional: For the last scene, before the rendered image is presented, the teams turn in their sketch for grading.

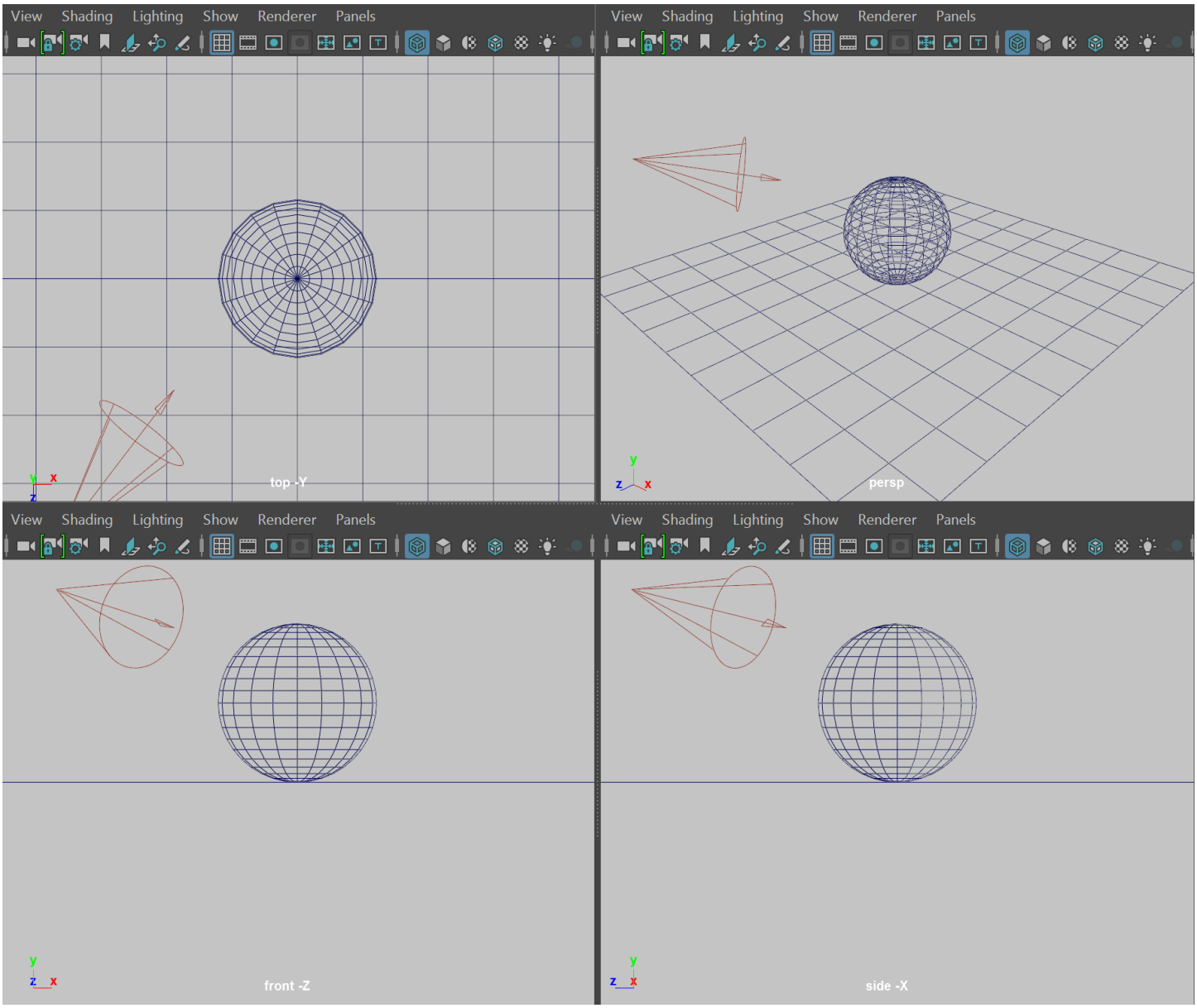
Rendering Activity Worksheet (Front)

Name(s): _____
_____
_____

On the image below sketch how the scene will appear when illuminated by the spot light. Pay careful attention to the edges of cast shadows and the terminator of form shadows. Treat all the objects in this scene as diffuse (Lambert) surfaces (i.e., no highlights).

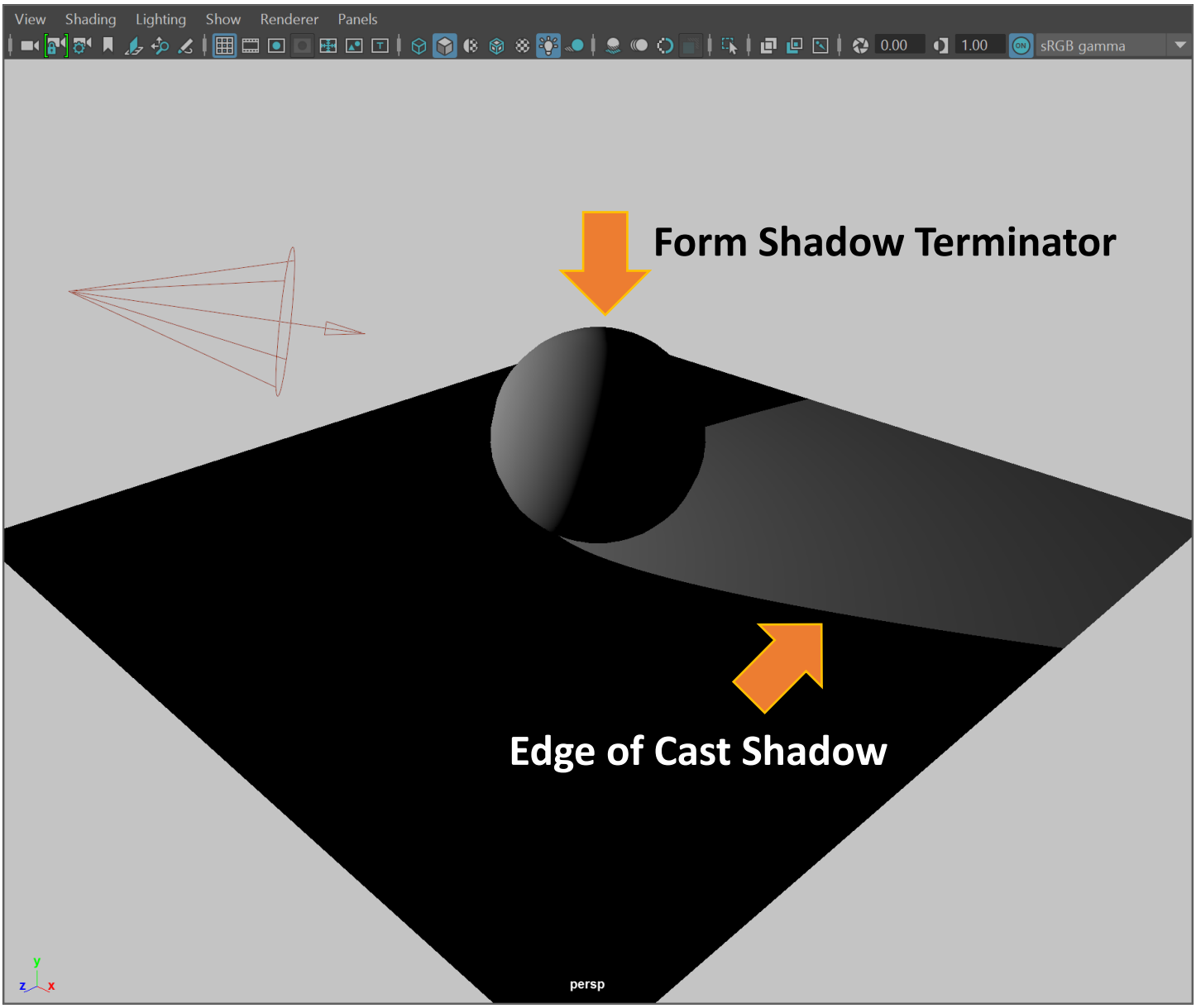


Rendering Activity Worksheet (Back)



(Since each person on the team will have a copy of the worksheet collectively they will be able to examine at both sides simultaneously.)

Rendered Image of the Scene



The rendered image will be shown to the students after they've sketched their own version of what they believe it should look like.

Appendix C
Post-Class Individual Space Assignment

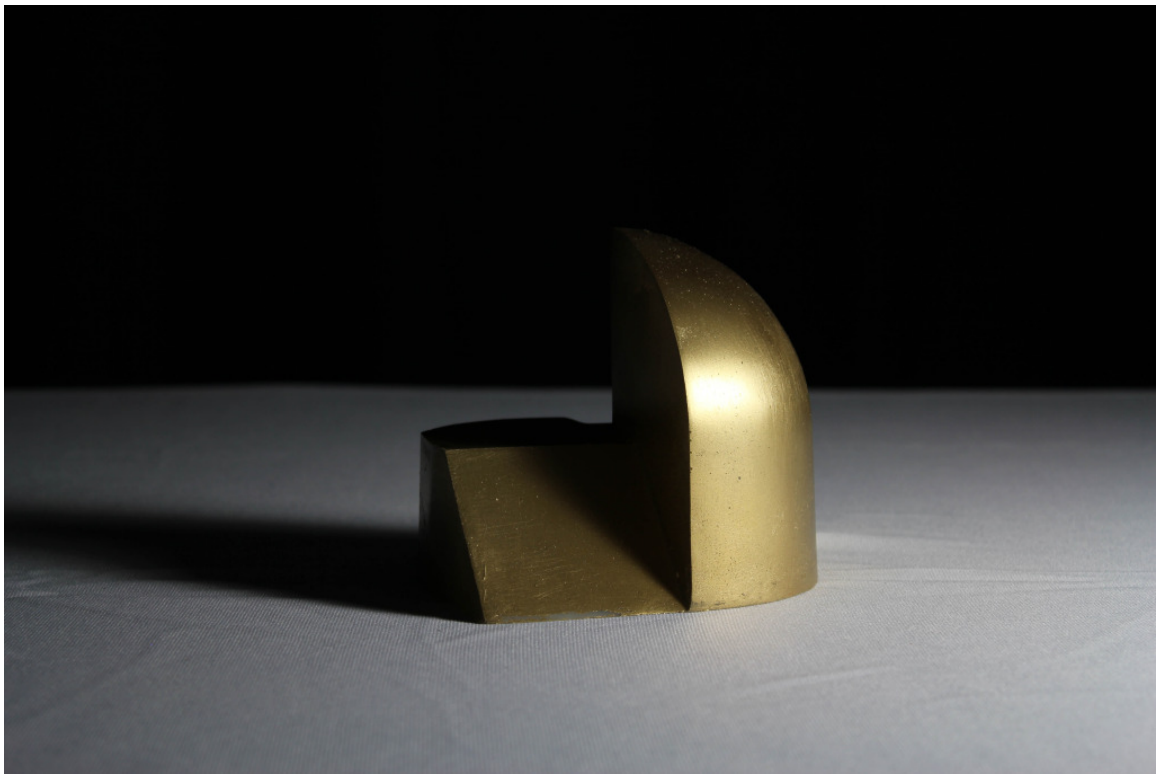
The following homework assignment will allow students to apply what they learned in the Group Space activities.

Recreating Cameras and Lights in Maya

NOTE: If you prefer, you may use Blender for this assignment instead of Maya.

For this assignment you will take a photograph of a real object(s) and try to match the camera and the lighting. Each person will have a choice of four photographs; for the assignment match any one of these photographs (for extra credit, do more than one). To find the photographs assigned to you, go here: [Link to list].

As an example, suppose that your photograph looks like this:

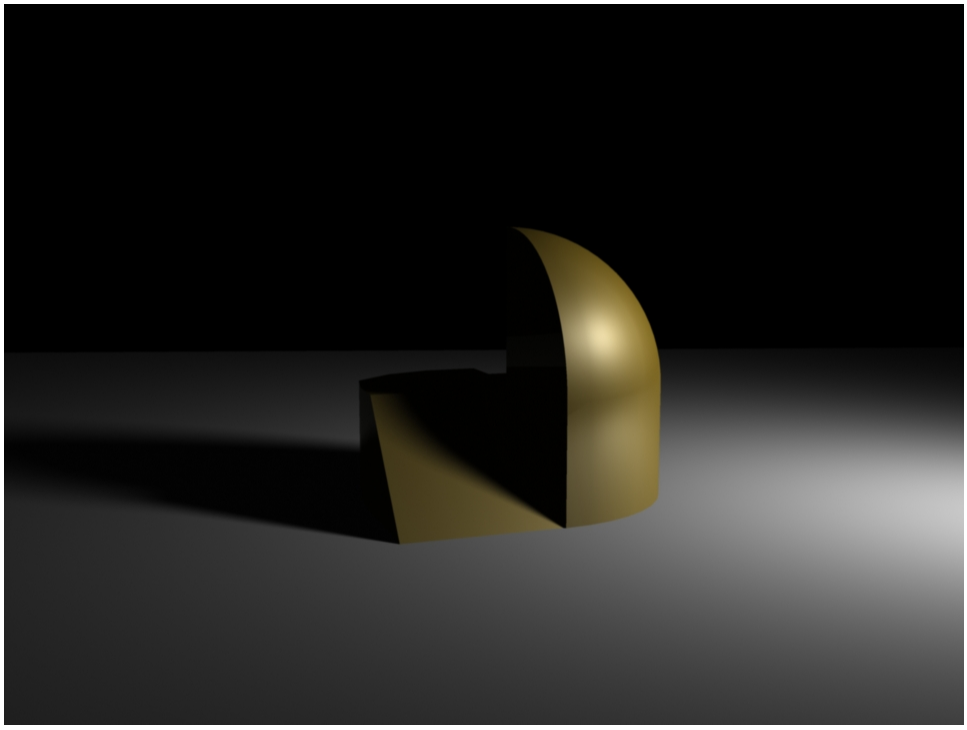


The model for this "widget" object has been created for you and may be downloaded here:

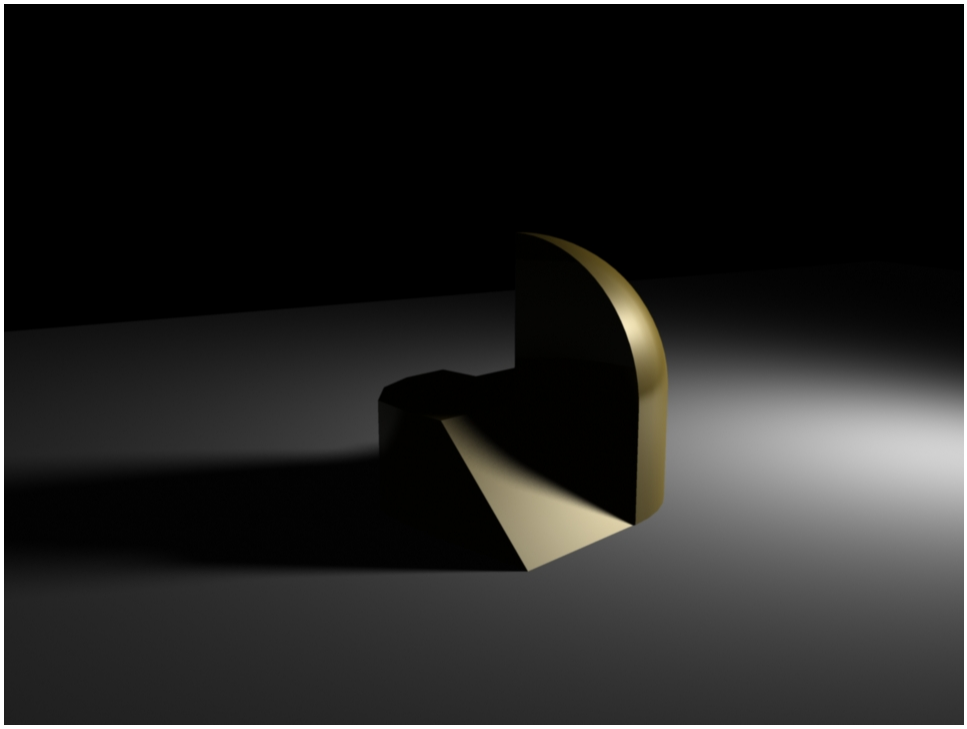
[Download Maya file] or [Download Blender file]

Use File -> Import to open the object in Maya or Blender. Create a surface for it to sit on, position the camera, add some lights, and adjust everything until your rendered image looks as closely as

possible to the photograph. Try to match any colors, for the object and the lights, as well as the details of the shadows (e.g., penumbra angles). For example, your render might look like this:



The image above is a pretty good match but not perfect; if you work at you may be able to get an even closer match with the photograph you choose to work with for this assignment. To finish, move the position of your camera to view the scene from another direction (suggest that you turn the camera roughly 45 degrees to either side). Create a second rendered image, such as this one:



Finally. upload the photograph you chose to use and the two rendered images into a blog posting entitled "Recreating Cameras and Lights in Maya." Note that this is a new assignment this year so there are no examples from previous semesters; contact me if you have any questions. Finally, for more info on using lights in Maya, see these lecture slides by Prof. Raquel Coelho.

Photography Alternative: One of the four photographs is a pair of soup cans. Recreate the camera and lighting in that photograph as accurately as possible then take your own photograph of the scene. Finish by taking a second photograph with the camera positioned about 45 degrees to either side of its original position. Upload both of your photographs as well as the photograph that you're matching. Note that it will not be easy to duplicate the lighting conditions using common house lamps; only do this alternative if you find it absolutely impossible to work with Maya or Blender.

Here are some Maya lighting tutorials that you may find helpful:

http://youtu.be/baIsLZcWK80 (Links to an external site.)

http://youtu.be/fyRkDYDBzls (Links to an external site.)

Here are some good examples from earlier semesters:

http://fionasphyshomework.blogspot.com/2012/11/recreating-lights-and-camera-in-maya.html

http://taylorlambertphys123.blogspot.com/2012/11/recreating-cameras-and-lights-in-maya.html

http://nickmaksimphys123blog.blogspot.com/2012/11/recreating-cameras-and-lights-in-maya.html

40 points (20 points if late and not eligible for bonus points if late)

Have a question? Go here.