CMPE 360

Fall 2023

Project3 - PART1

Blender Basics

The first assignment is about to Blender Basic. Follow the steps carefully and be aware of the Checkpoints below. Make sure you complete each one since we will do the grading based on them.

1. Blender Basics

What is Blender? Blender is a free and open-source 3D creation suite. It supports the entirety of the 3D pipeline—modelling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. Examples from many Blender-based projects are available in the showcase. (from Blender website)

What we'll do with Blender in this course? We will learn the basics of modelling, texturing, shading, and rendering inside Blender. We'll also use Blender's API for Python scripting to write a custom raytracing render engine. Blender is well suited to this class because of its unified pipeline and responsive development process.

- Download Blender from this link :
  https://download.blender.org/release/Blender3.5/

For Windows, you can choose Installer after downloading, pass the steps with Clicking Next and Blender will open automatically.

☐ Checkpoint 0: Run Blender

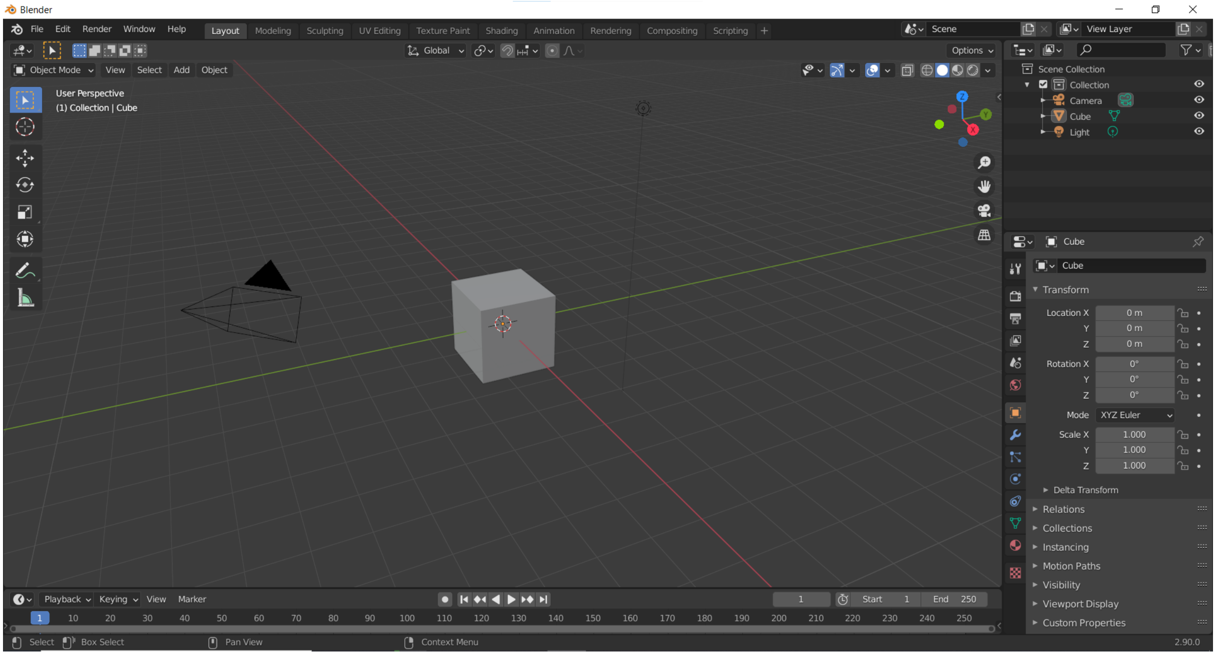


Figure 1:

3D Viewport (yellow), Outliner (green), Properties (blue) and Timeline (red). From Blender documentation.

This is the default workspace for blender (see more at blender documentation):

- 3D Viewport on top left (yellow)
- Outliner on top right (green)
- Properties editor on bottom right (blue)
- Timeline on bottom left (red)
- Blender has a nice official introduction playlist for 2.8 on their YouTube channel. They're compatible with 2.90 and later. If you haven't used Blender before, please watch the first two videos to learn the basics of how to get around inside Blender. But don't worry, we will still provide detailed instructions below to help you get started. We have also included some links to Blender documentation if you want to further investigate the tool.

2. Manipulate the Scene

- The default scene comes with a cube. We can add/delete objects in the scene. Blender stores some basic objects that we can directly add to the scene without constructing them from scratch. Here we will delete the cube and add a UV sphere.

- Move your mouse over the cube, left click to select. An orange outline will appear around the cube. Hit the Delete key to delete the cube.

  Then go to the menu bar on top, go to Add ‣ Mesh ‣ UV sphere (or leave your mouse inside the 3D viewport, and use the shortcut Shift A). A sphere should appear in the center of the scene.

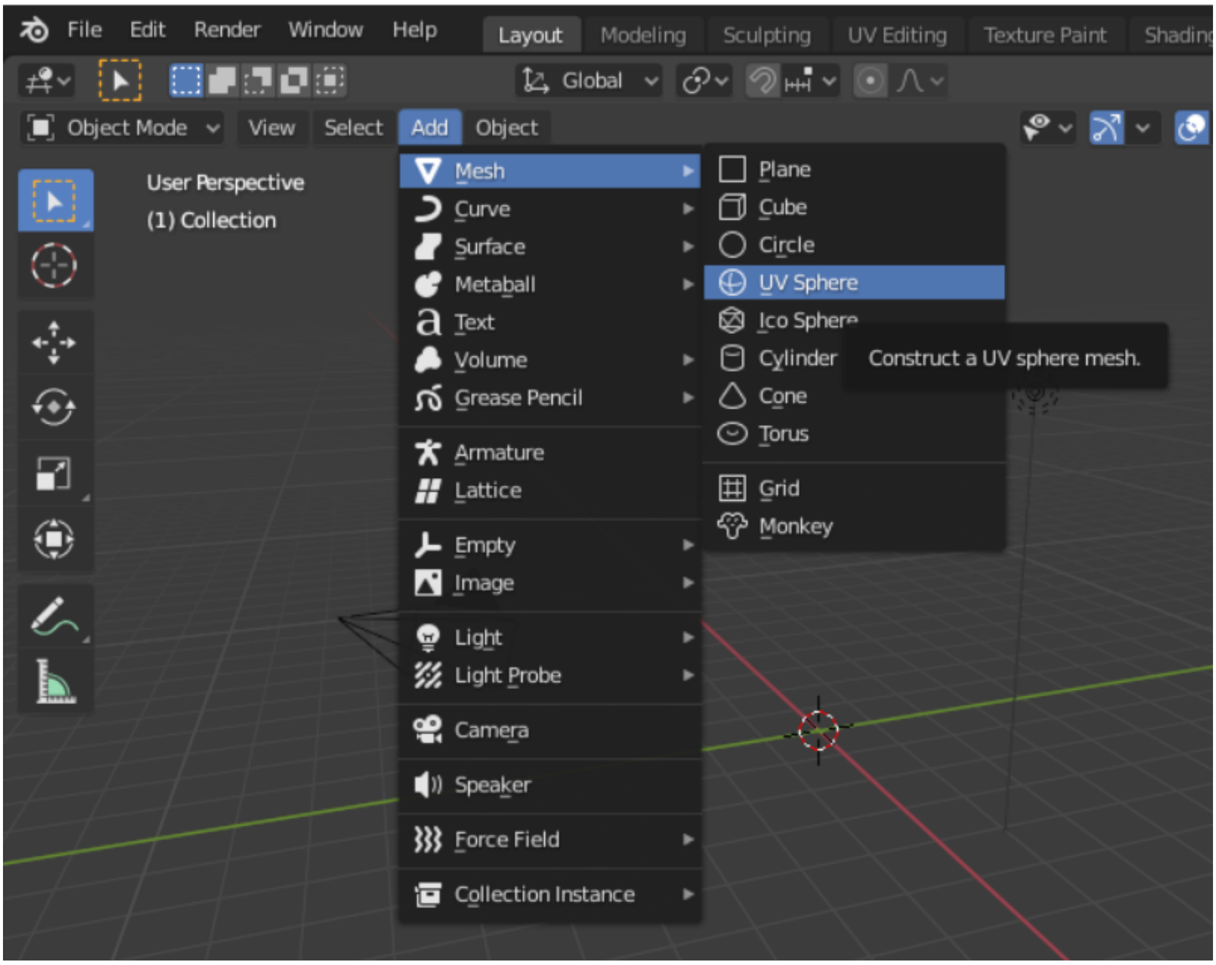


Figure 2

➢ **Set up editor and workspace**

- (Optional but recommended for first time users) First set up the editor. This will keep the render in the same window, without popping out a new window every time.

Go to the top bar, Edit ‣ Preferences (From Figure 3).A new window should pop up, on the sidebar select Interface, on the right change the option for Editors ‣ Temporary Window ‣Render in to Image Editor (From Figure 4).

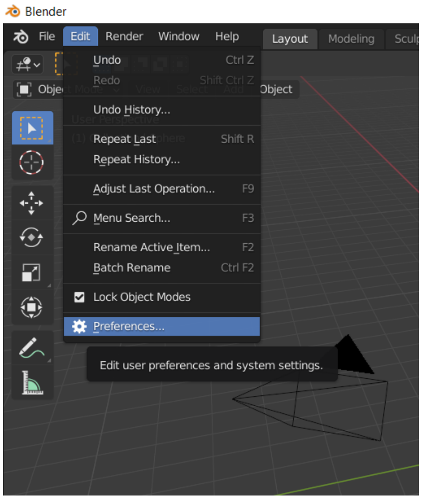


Figure 3

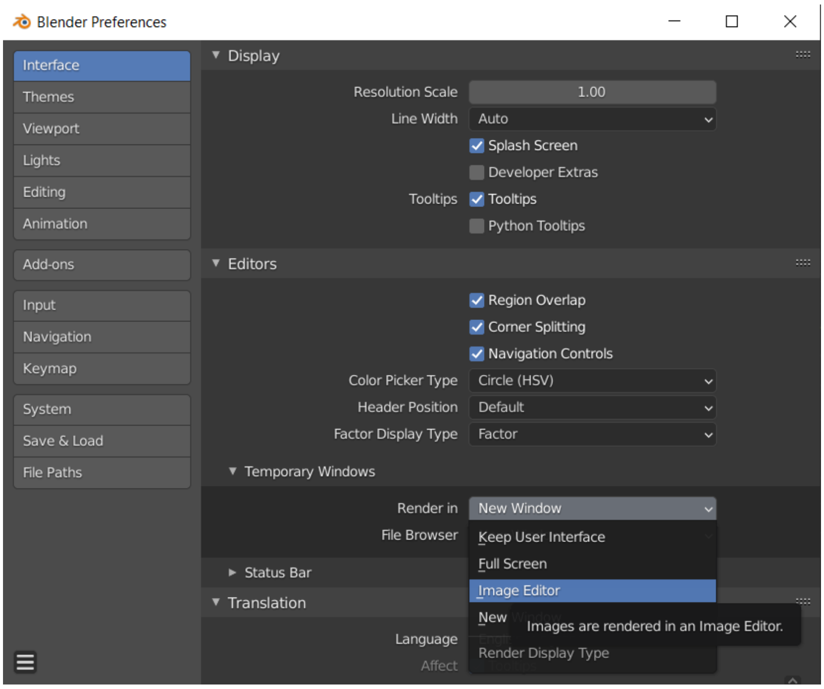


Figure 4

(Optional but recommended for first time users) Then setup the workspace: adding an Image Editor. This will be where we see our render results inside Blender. It will be more convenient than go to your file explorer and open the rendered image.

Hover the mouse over the top right corner of the 3D viewer (Figure 5). The cursor will change to a cross. Drag left to create a new area. In the top left of the new area, change the editor type to Image Editor. Your editor should look like Figure now.

For more detail about areas and how to manipulate them, go to the [documentation]() or the [tutorial video]().

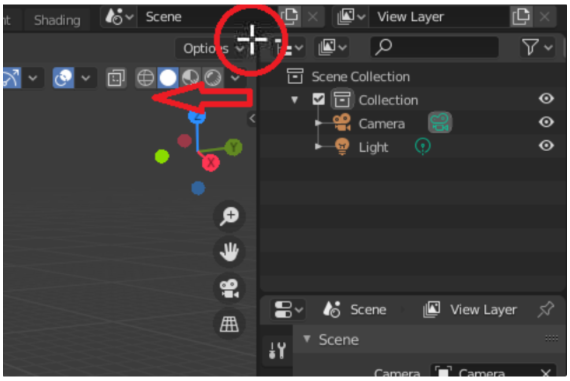


Figure 5

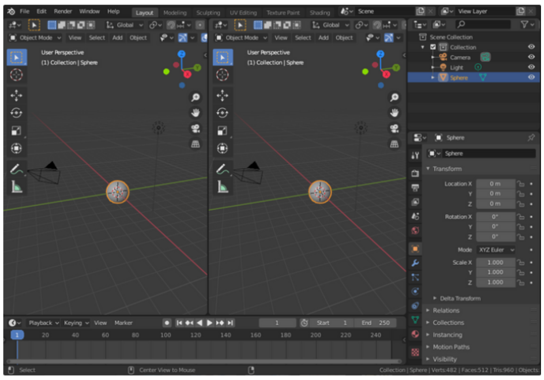


Figure 6

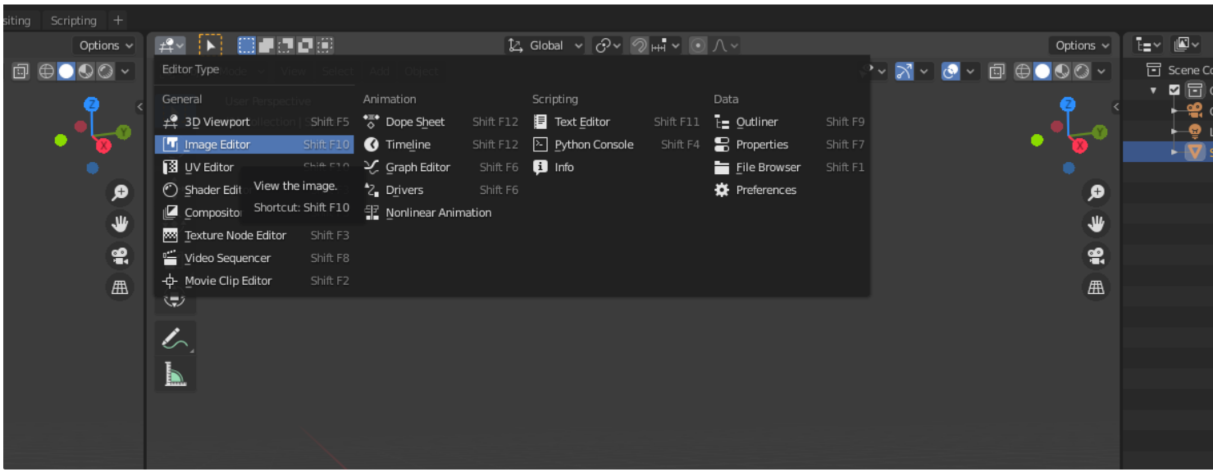


Figure 7

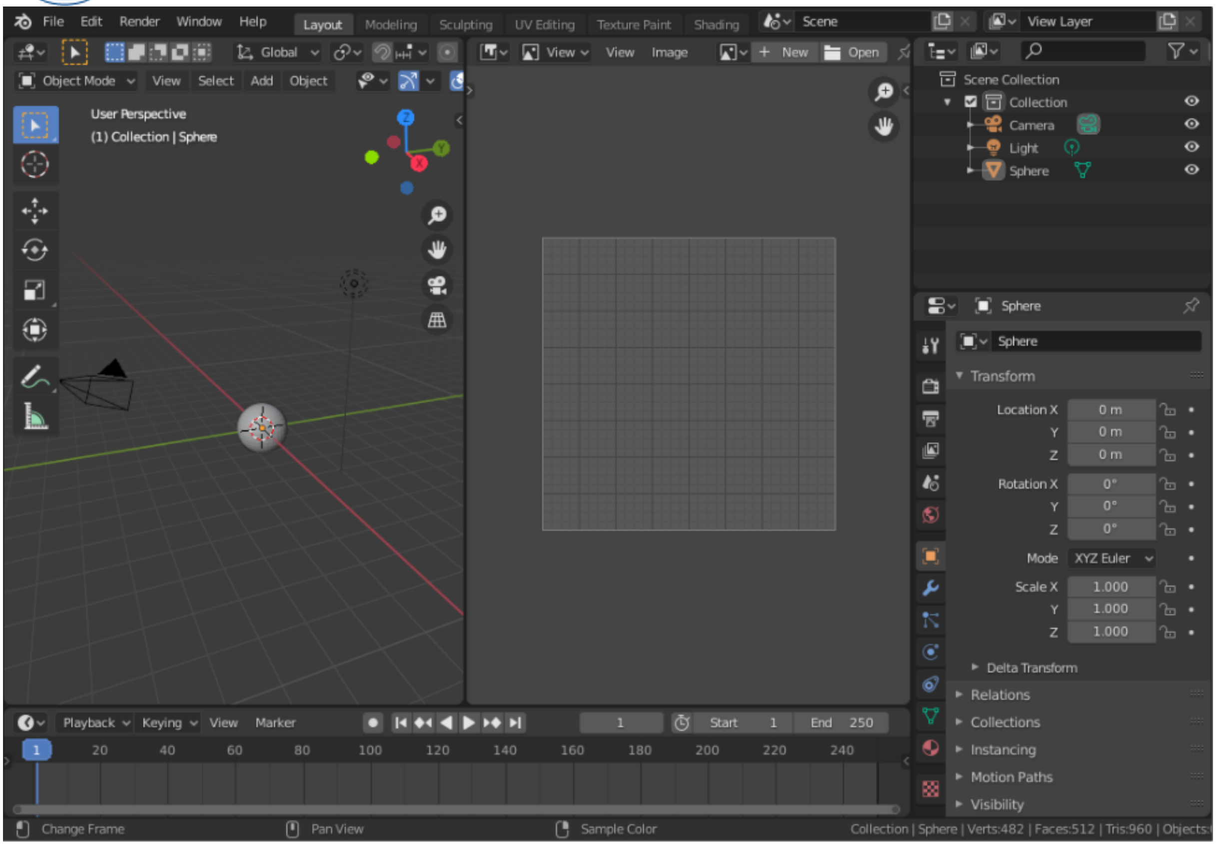
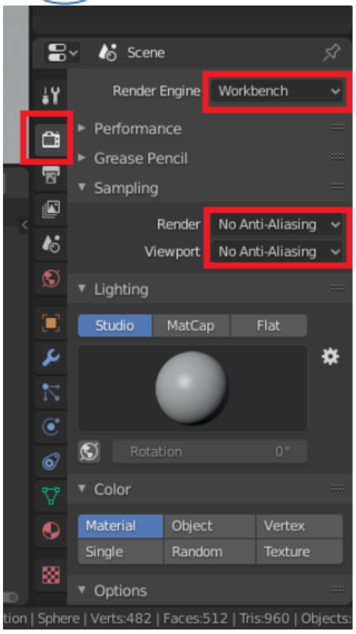
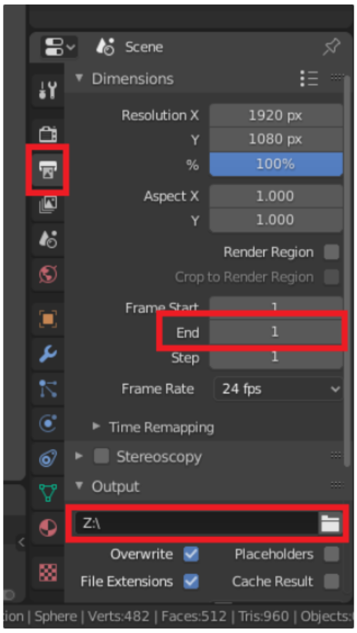


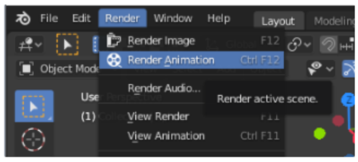
Figure 8

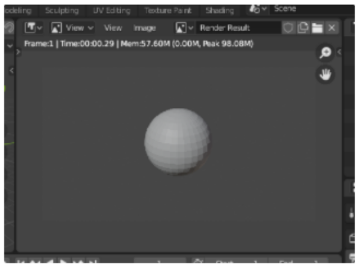
3. Render and Save Image

- After that, change the render settings and render the image. We want Blender to save a single rendered image. By default Blender only saves animations, so here we change the length of the animation to 1. Also, we are playing with the default viewport scanline renderer in this homework, so we will change the render engine to Workbench.
- Go to the Properties Editor (bottom right), select the camera icon (Render Properties) on the sidebar. Change the Render Engine to Workbench, and the Sampling for Render and Viewport to No Anti-Aliasing
- Then click on the printer icon (Output Properties) on the sidebar. Change the Frame End to 1 and Output Path to a place on your local machine where you want to save your rendered image to .
- Now render the image by going to top bar, Render ‣ Render Animation (or shortcut Ctrl/Cmd F12) to render the image and save it to the specified path automatically. The rendered image will also show up as "Render Result" in the Image Editor we created in the previous step .









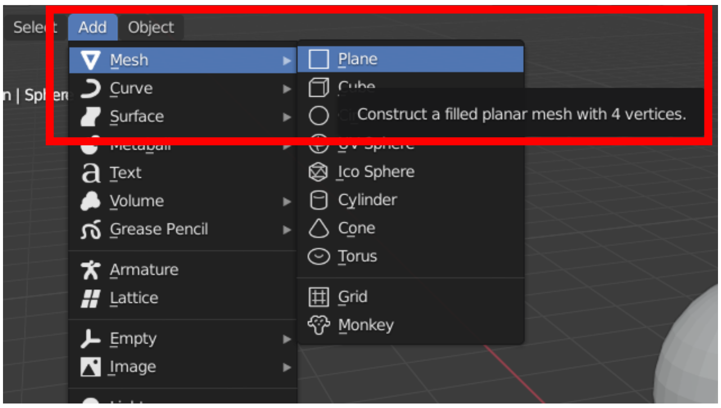
If you only want to render the result in Blender without saving the image, use Render ‣ Render Image (or F12) instead.

Now you have rendered your first image in Blender! Note that this image is rendered from the camera's perspective.

☐ Checkpoint 1: Save the Rendered Image of the Default Sphere

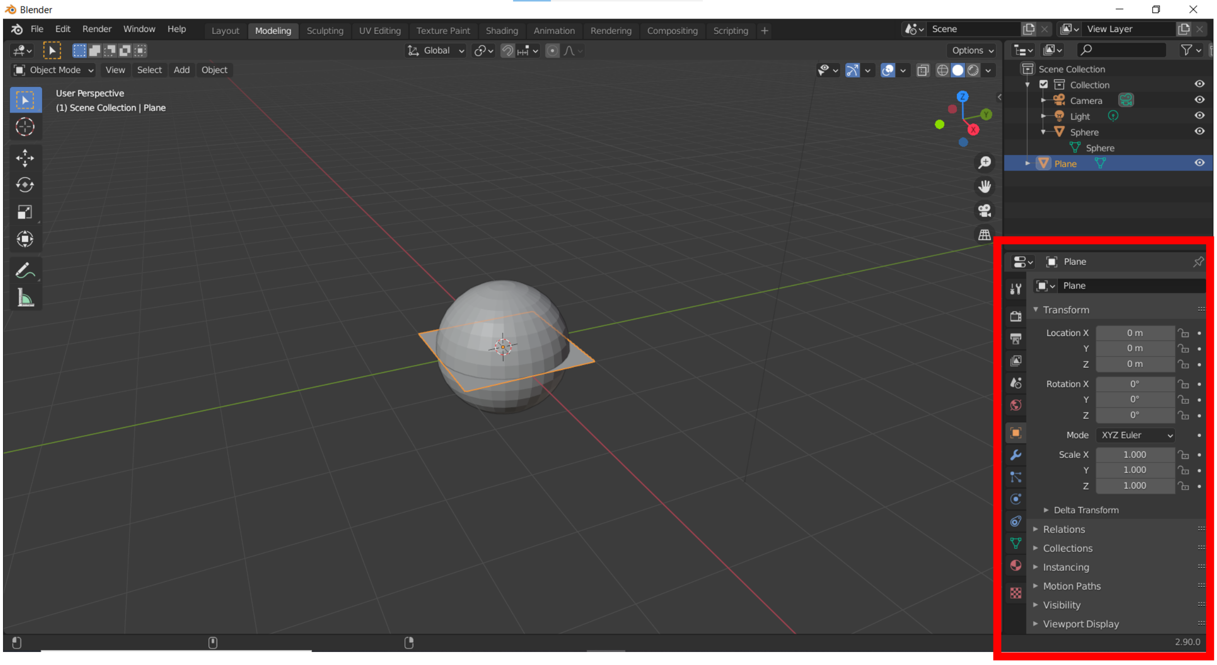
4. **Add a plane and change the scale**

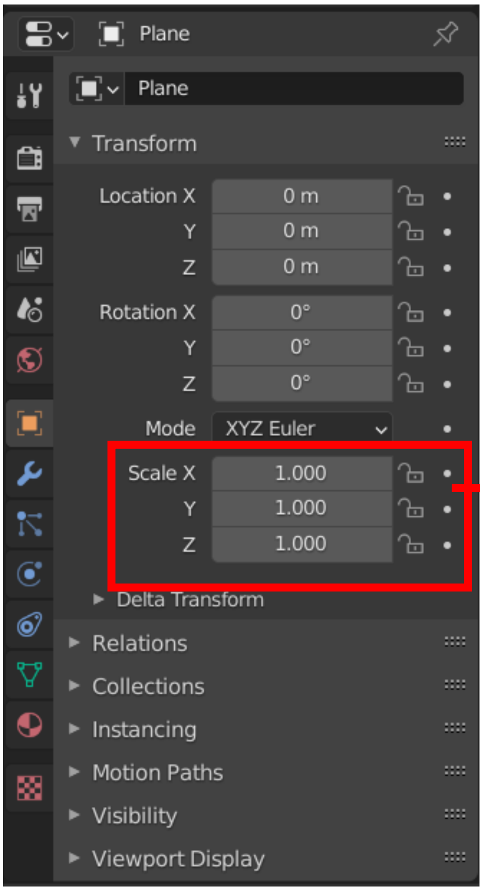
We will add a new plane. Then go to the menu bar on top, go to Add ‣ Mesh ‣ Plane.



You should see the scene below. You will change the scale of plane.

Change the Scale X to 2, Y to 2 and Z to 2.



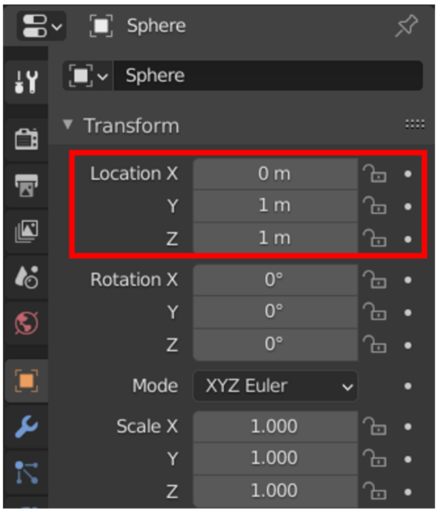


You will change the scale of plane here.

5. Change Location to the Objects

Left-click on the sphere to select it. Go to Properties Editor ‣ Object Properties, change the location.

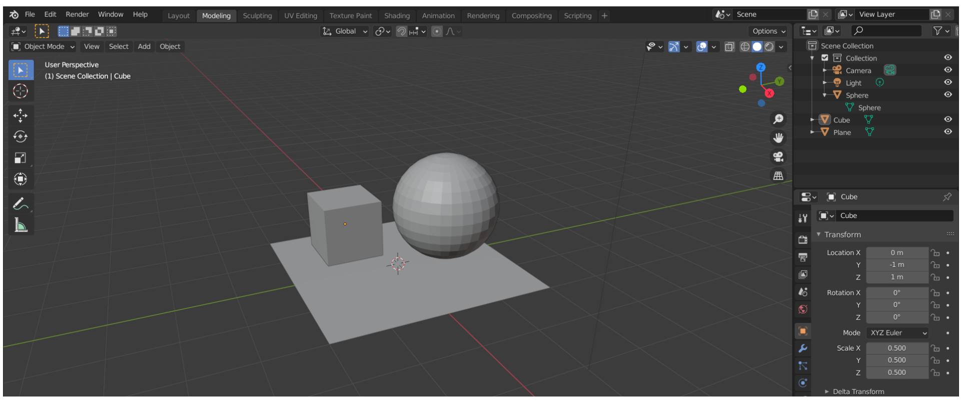
- X to 0
- Y to 1
- Z to 1 like below.



☐ Checkpoint 2: Save the Rendered Image of the new scene that have a plane and sphere with changes.

6. Add a cube and change the location

Go to the menu bar on top, go to Add ‣ Mesh ‣ Cube. Left-click on the cube to select it. Go to Properties Editor ‣ Object Properties, change the scale X to 0.5, Y to 0.5 and Z to 0.5. After that from same bar, change the location X to 0, Y to -1, and Z to 1.

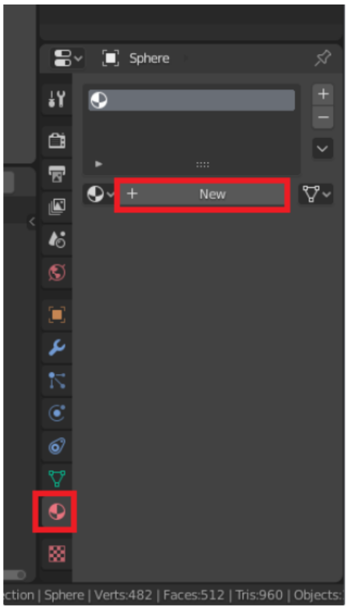


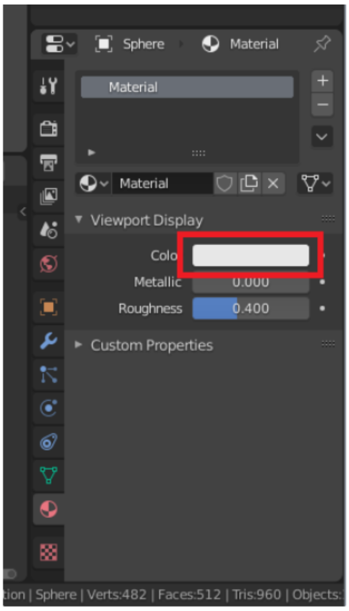
☐ Checkpoint 2.1: Save the Rendered Image of the new scene that have a plane, sphere and cube with changes.

7. Add Material and Change Color

We can add color, texture, and various shaders to objects to make them more appealing. In 3D software, it is usually done by first adding a material to an object, then changing the settings of that material. We are only getting started now in a very basic scanline renderer, so our options are limited for now. Let's add color to the sphere first. We will play with lighting and shaders in other renderers in future homework.

Left-click on the sphere to select it. Go to Properties Editor ‣ Material Properties, click the New button to add a material to the sphere . Under Viewport Display you can change the Color. In the pop-up color palette , you can move the dot in the color field and the slider to change the color.





After changing color of sphere you will see window like example. (Figure 9) **Now, pick any purple color for the sphere.**

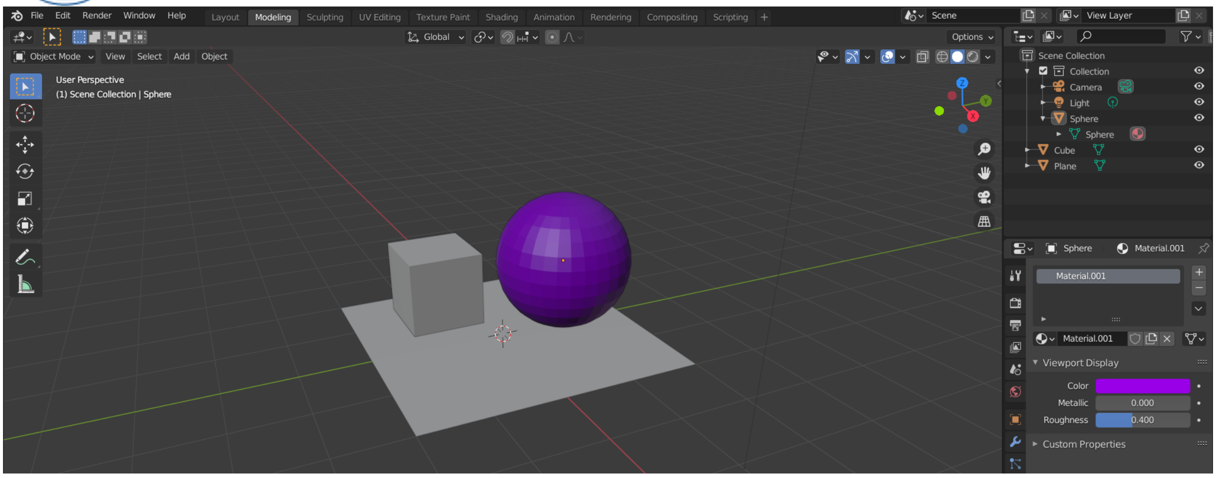


Figure 9

After that change to sphere color, Left-click on the cube to select it. Go to Properties Editor ‣ Material Properties, click the New button to add a material to the cube. Under Viewport Display you can change the Color. In the pop-up color palette, you can move the dot in the color field and the slider to change the color. **Change the cube color to green. And change the plane color to blue.** Render the image and save it.

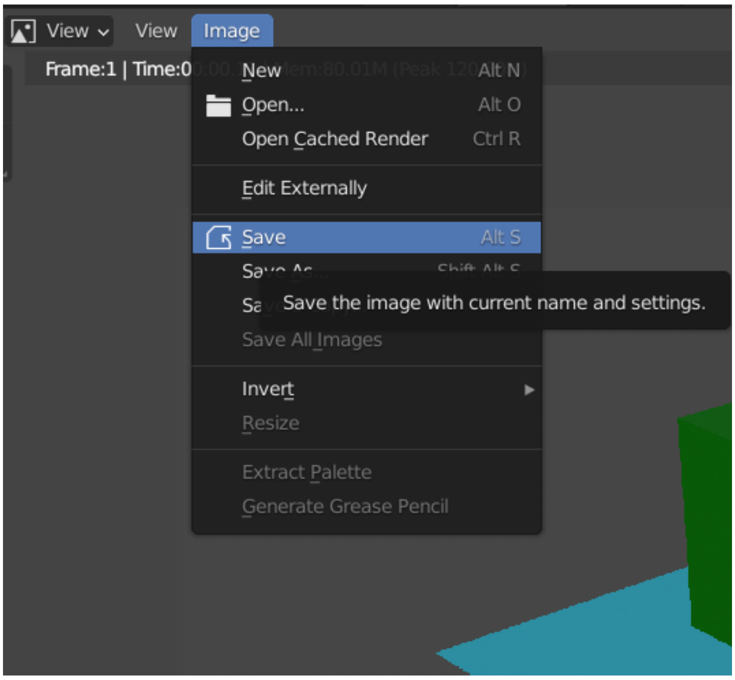


Figure 10: To save the image Image→ Save

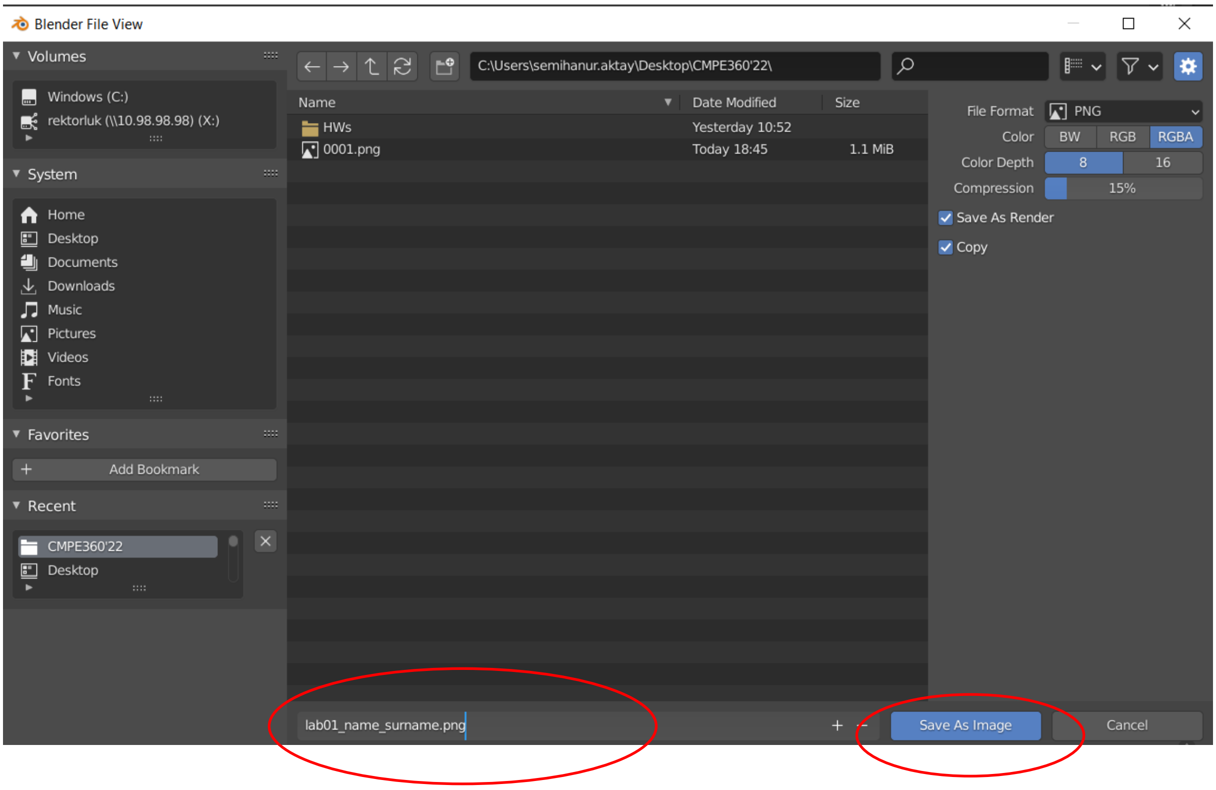


Figure 11

☐ Checkpoint 3 : Save the Rendered Image of a purple Sphere, green Cube and blue Plane.

7. Change Render Resolution

We can change the resolution of our image. If you want a clearer image, render at a higher resolution (larger X and Y). Vice versa, render at low resolution (lower X and Y). Here we want you to see and analyze the effect of tuning the resolution way down.

Go to the Properties Editor (bottom right), select the printer icon (Output Properties) on the sidebar.

- Change the Resolution X to 160, Resolution Y to 90. Make sure the Resolution % stays at 100.
- Change Resolution X to 3840, Resolution Y to 2160. Make sure the Resolution % stays at 100.

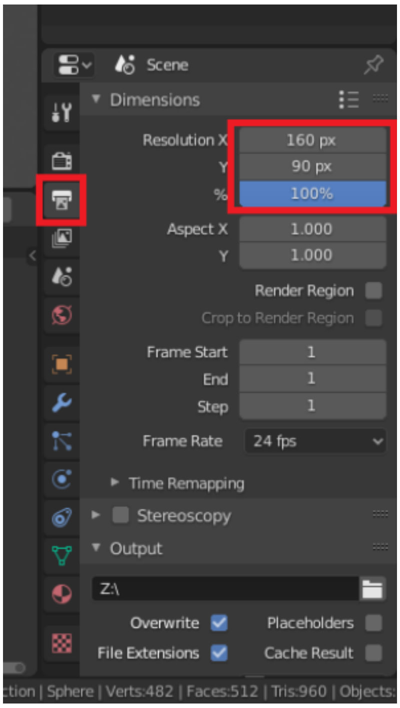


Figure 12

☐ Checkpoint 4: Save the rendered images of the purple sphere with a resolution of 160x90.

☐ Checkpoint 4: Save the rendered images of the purple sphere with a resolution of 3840x2160.

☐ Checkpoint 4: Compare the images from Checkpoint 3, Checkpoint 4 and Checkpoint 5. Discuss the effect of changing the resolution. (Write your document file)

8. Change Gamma

In lecture, we talked about Gamma Encoding and Correction. Correct display of renders requires conversion to the display device color space. We are going to change the gamma value and compare the result.

Note that we are not changing the actual color space conversion, but rather adding extra gamma correction applied after the default display transforms. This mainly acts as an additional effect for artistic tweaks. For more information, see the [Blender documentation](#).

First, change the resolution in Properties Editor ‣ Output Properties back to 1920x1080. You can also right-click on the value, and select Reset to Default Value.

Then go to the Properties Editor ‣ Render Properties. Change the Color Management ‣ Gamma to some other value. (Figure 13)

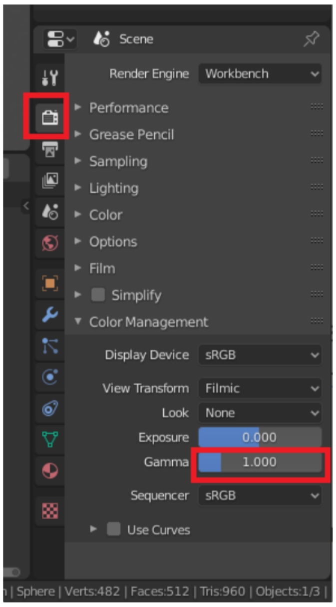


Figure 13

☐ Checkpoint 5: Save the rendered image of the purple sphere, green cube and blue plane with a gamma value 3.

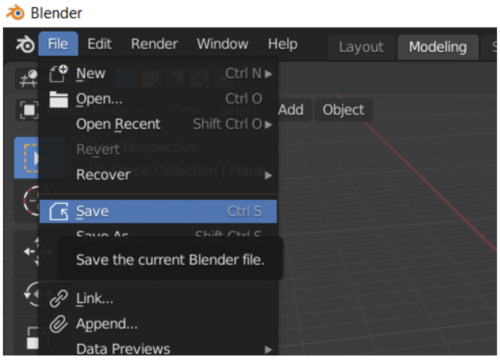
☐ Checkpoint 5: Save the rendered image of the purple sphere, green cube and blue plane with a gamma value 5.

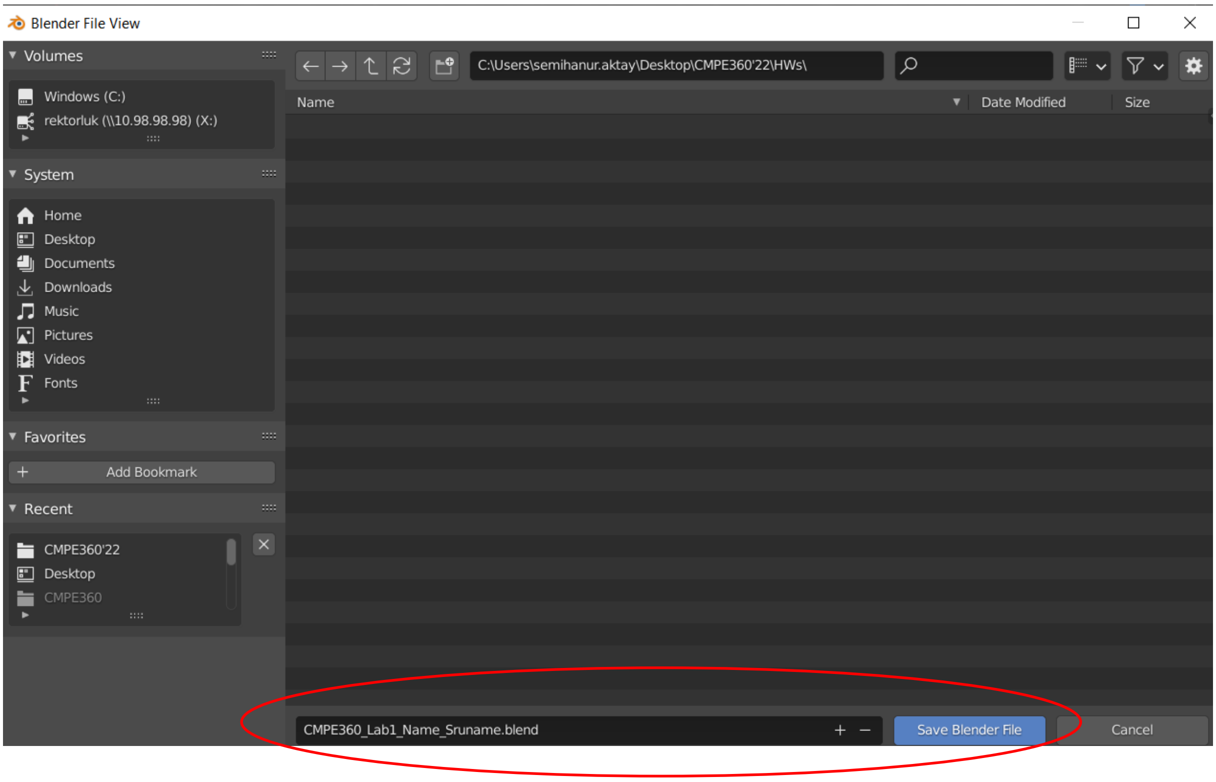
☐ Checkpoint 6: Compare the images from Checkpoint 3 and Checkpoint 5. Discuss the effect of changing the gamma value.

HOW CAN I SAVE MY BLEND FILE ON MY COMPUTER?

Go to File→Save.

Your file name format should be “CMPE360_Project3_Name_Surname”.





PART2

Objects and Camera

Follow the instruction carefully. Be aware of the Checkpoints below. Make sure you complete each one since we will do the grading based on them.

1. Objects and Transforms

- In Blender, we can translate, rotate, and scale objects. We can also parent one object to another to move them around together. The "object space" and "world space" corresponds to "local coordinates" and "global coordinates" in Blender.

- First, add a cube to your scene. If you open Blender with the default scene, it should come with a cube already. You can use that cube for this part of the homework.

(Optional Reading) How to transform objects in Blender

- If you are new to Blender, we recommend watching this video "Select & Transform" first before proceeding. You can skip this part if you are familiar with Blender.

You can use the tools in the Toolbar of the 3D viewport: Move, Rotate, Scale, and Transform Tool to transform the object (fig 1). When you select an object, the orange dot indicates the origin of the object.

The keyboard shortcuts are G (for grab), R (for rotate), and S (for scale). You can press X, Y, or Z afterward to lock the transform to that specific axis. For example, if you press G, then X, then move your mouse, the object will only translate along the X-axis. You can also type in numbers after pressing the keys to specify the exact values you want to move, rotate, or scale. For example, if you press G, Z, 2, the object will translate 2 units along the Z-axis.

Make sure your cursor is in the 3D viewport area when pressing the keys. Blender uses cursor location to determine which area you want to send your keystrokes to.

You will be able to view/change the local transform of the object in two places: 1 (the sidebar of the 3D viewport by pressing N, and 2) Property Editor (bottom right)→ Object Properties. Under Transform, you should see the Location, Rotation, and Scale of the active object. You can change the values and see how the object changes. You can change the value by clicking on the value and dragging it left or right, or reset the value by hitting backspace. Remember these values specify the local transform, not global transform.

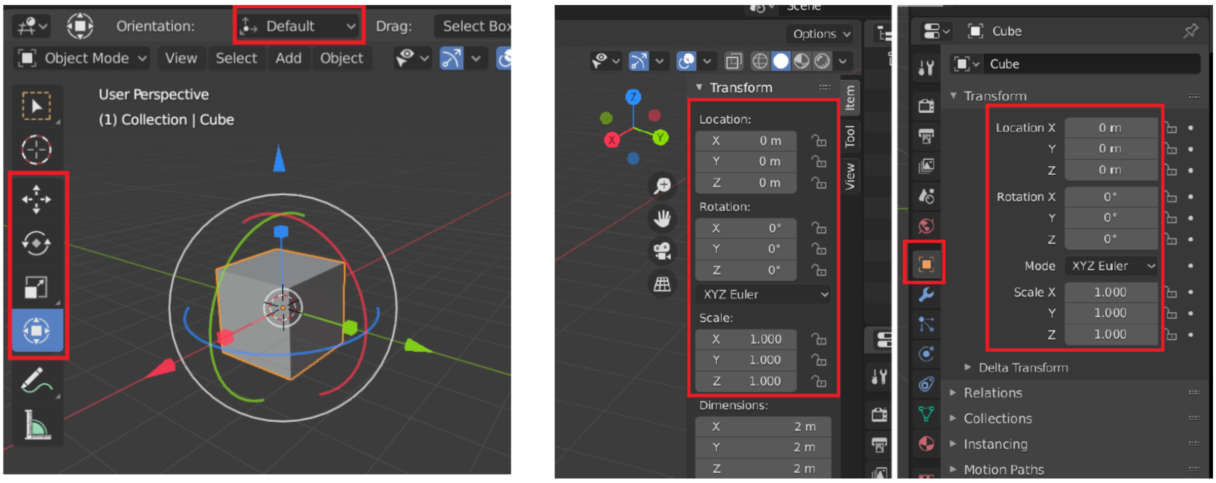


Figure 14

2. Order of Rotations

- To explore the ideas we introduced in the lecture, we will first investigate why the order of rotation matters. You will calculate the rotation matrices and verify your result with one of the vertices on the cube.

The default cube in Blender has a size of 2 units, which means its vertices are at locations of positive and negative 1s. We are going to use the vertex with location (Figure 2-colored in red) to see how rotations are constructed. The world (global) axis is shown by the navigation gizmo: X-axis points to the bottom left, Y-axis points to the bottom right, and Z-axis points upward.

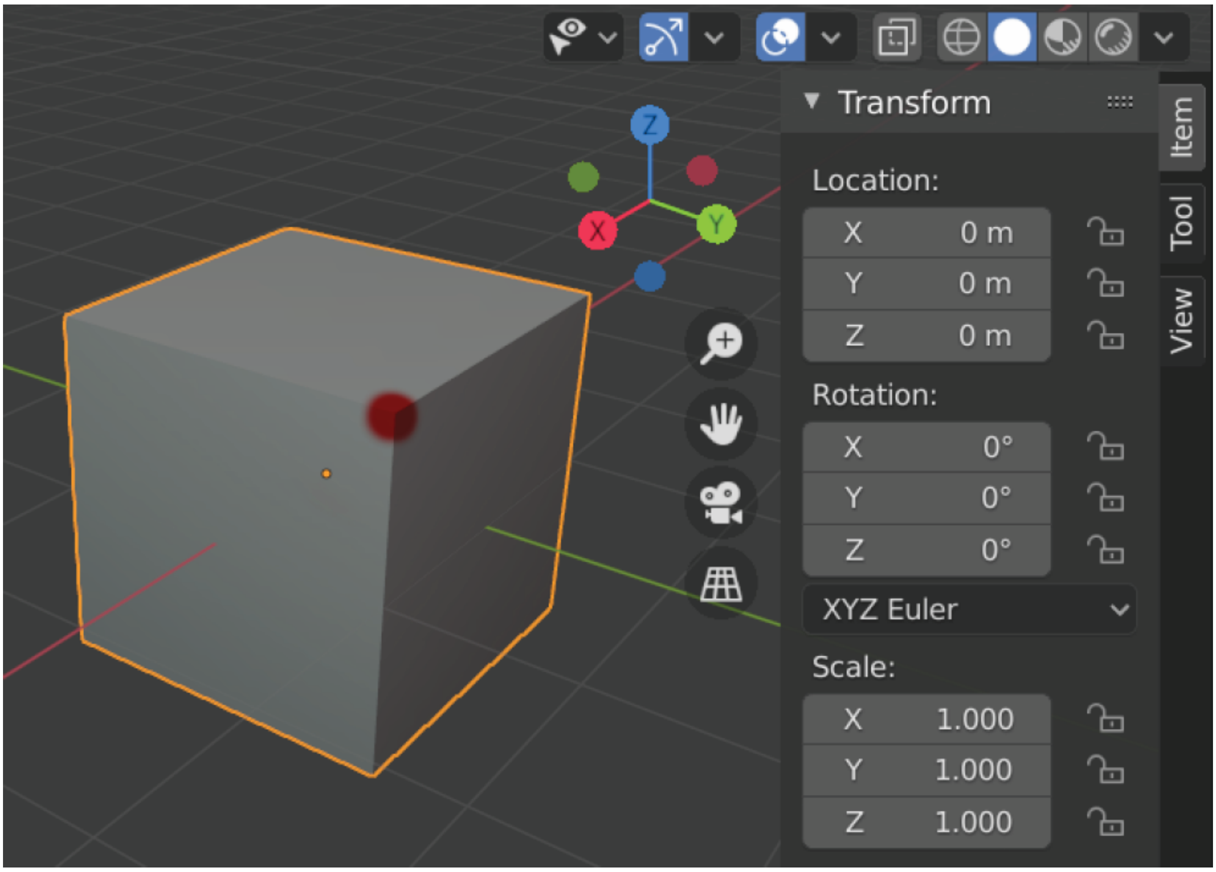


Figure 15

First, we rotate the cube along the global X-axis by +45°.Then rotate along the global Y-axis by +45° (Figure 3). Let p_{xy} denote the world location of vertex v after rotation. (Shortcut: R, X, 45, Enter. R, Y, 45, Enter)

Next, let us go back to the default cube, but this time, we rotate the cube along the global Y-axis first by +45°. Then rotate along the global X-axis by +45°. (Figure 4). Let p_{yx} denote the world location of vertex $\$v\$$ after rotation. (Shortcut: R, Y, 45, Enter. R, X, 45, Enter)

Write down the rotation matrices for each step, and then use them to:

- ☐ **Checkpoint 1: Write down p_{xy}** (be prepared to show your work during grading)
- ☐ **Checkpoint 2: Write down p_{yx}** .(be prepared to show your work during grading)

You are allowed to use calculator/write your own code to calculate the result.

Hint:

The final location of vertex p is calculated by multiplying the rotation matrix for each step (be aware of the order!) to the left of p=$\begin{pmatrix}1\\1\\1\end{pmatrix}$

Hint 2:

The rotation matrices for rotating along X-axis and Y-axis for 45° are:

$$R_x = \begin{bmatrix}1 & 0 & 0\\ 0 & cos\frac{\pi}{4} & -sin\frac{\pi}{4}\\ 0 & sin\frac{\pi}{4} & cos\frac{\pi}{4}\end{bmatrix}, \qquad R_y=\begin{bmatrix}cos\frac{\pi}{4} & 0 & sin\frac{\pi}{4}\\ 0 & 1 & 0\\ -sin\frac{\pi}{4} & 0 & cos\frac{\pi}{4}\end{bmatrix}$$

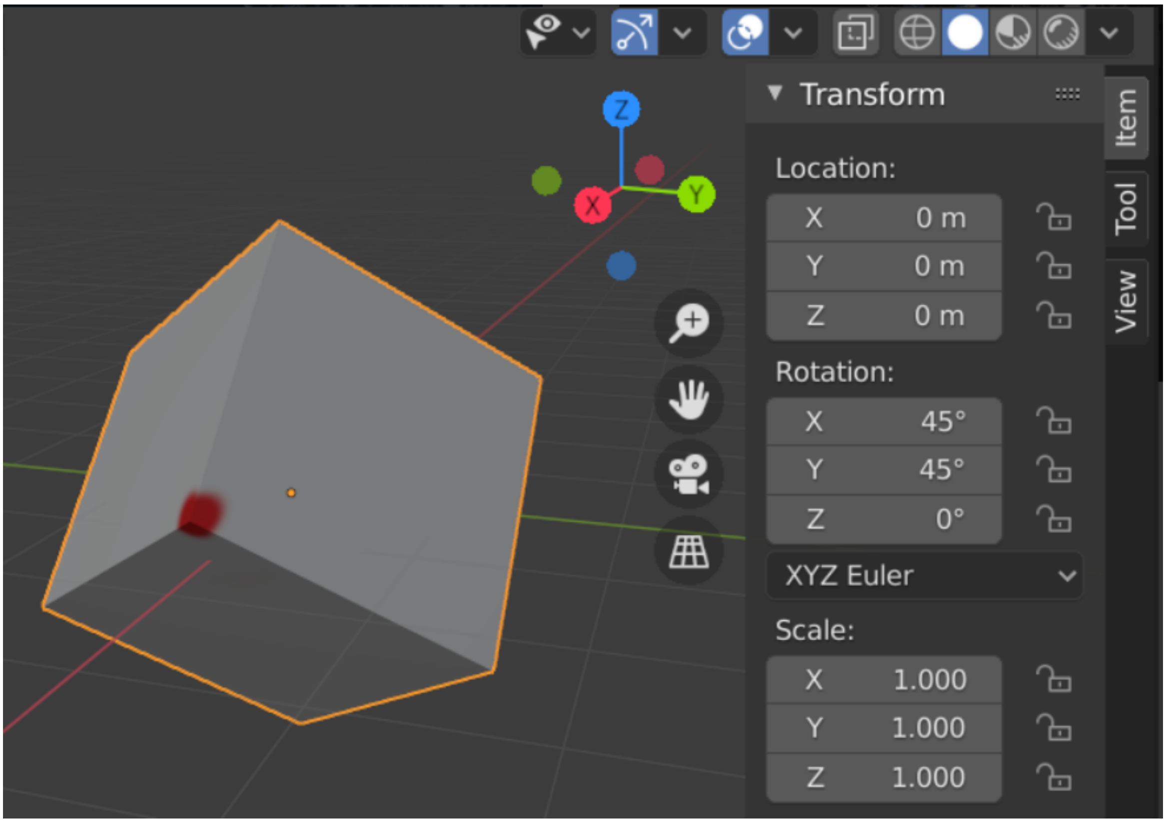


Figure 16

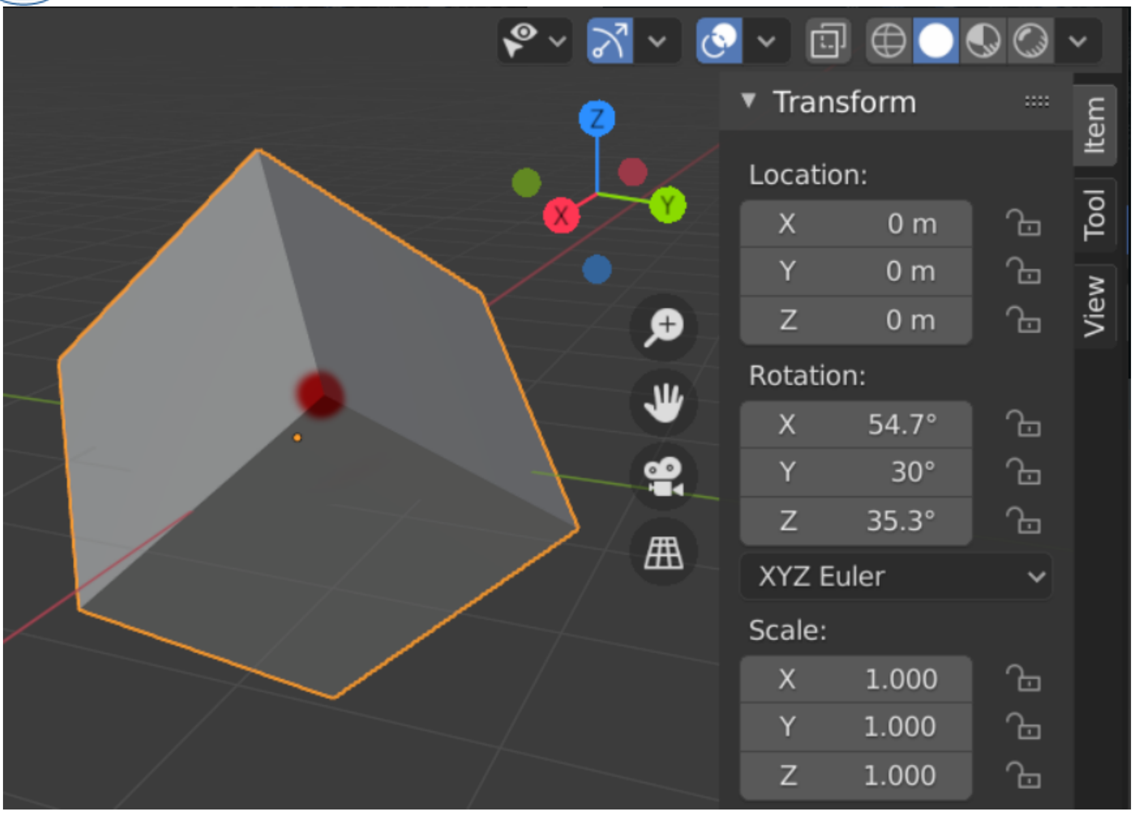


Figure 17

You may notice that you can choose various rotation modes for your object rotation. When you first rotate along Y-axis then X-axis, the rotation shows up as (54.7,30,35.3) in XYZ Euler mode instead of (45,45,0). If you change the rotation mode to YXZ Euler, the numbers will become (45,45,0). This is due to the different order of rotations when defining Euler angles. For more information, see rotation mode in Blender documentation.

3. Camera

Cameras are crucial to the virtual world. When you render, everything in the scene will be projected on to the camera film (screen space) to create your final image. In this section, we are going to play with the perspective camera and understand the effect of focal length. This is exactly how dolly zoom (or vertigo effect), a famous camera effect, works.

First, we are going to set up the scene. Open a new Blender file, delete the cube . Add a monkey (Figure 5). Set the camera location to (0,-6,0) and rotation to (90,0,0).

The scene should look like Figure 6. Press the camera icon to go to the camera view.

Select the camera, and change its focal length to 25mm (Figure 7).

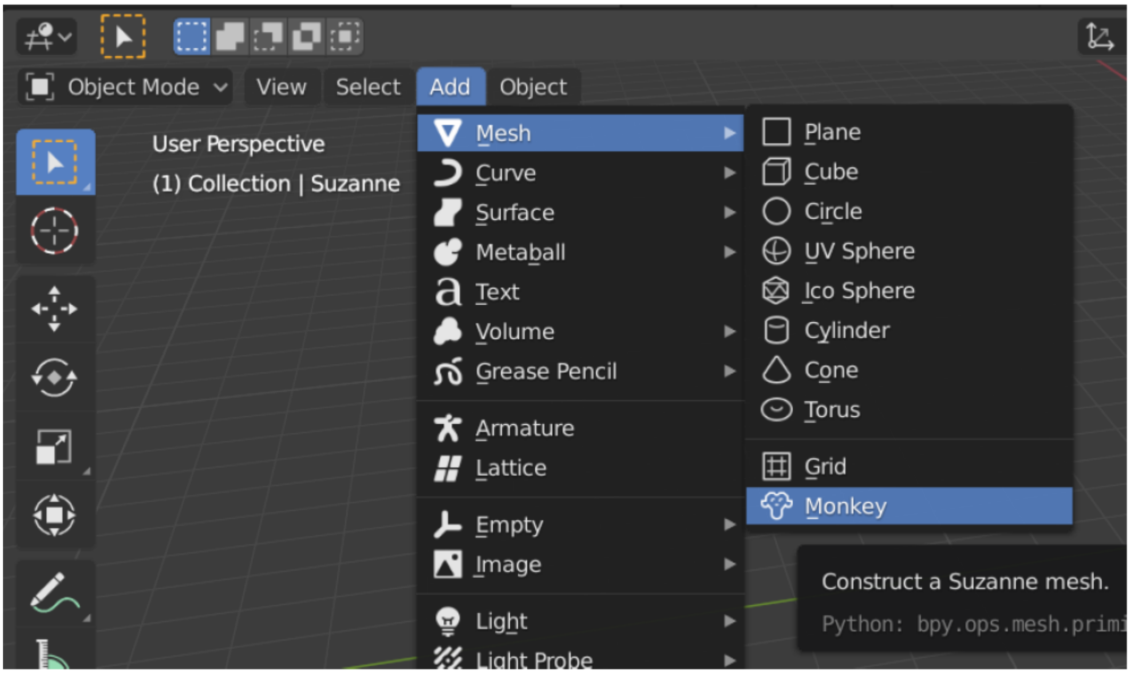


Figure 18

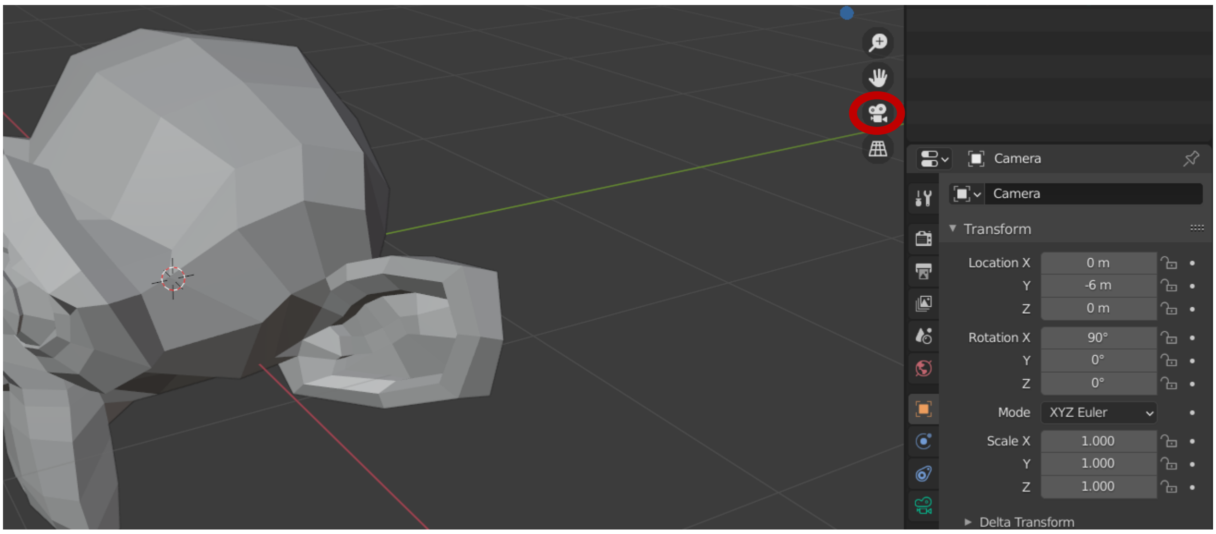


Figure 19

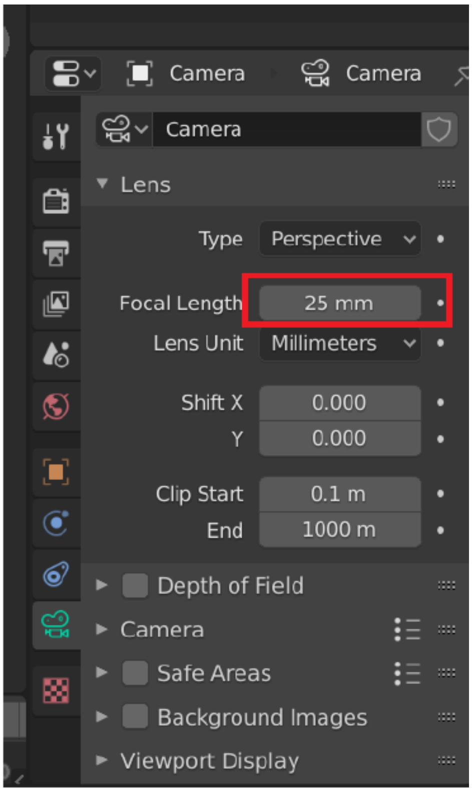
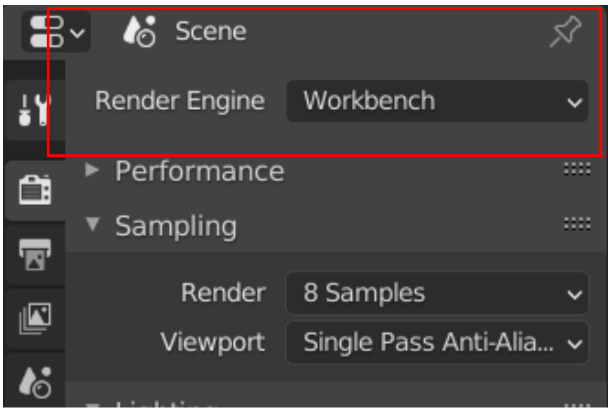
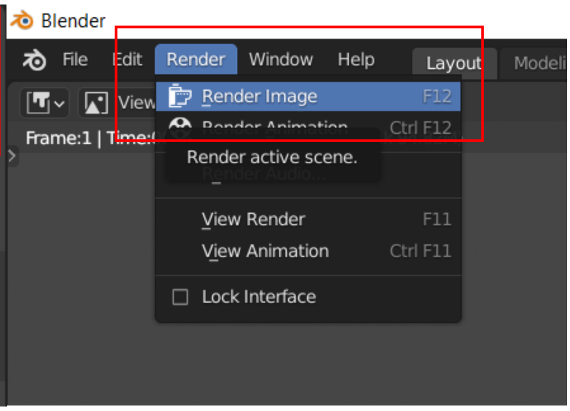


Figure 20

Set the render engine to Workbench, and render the image.





Change the camera location to (0,-10, 0) and focal length to 60 mm. Render the image.

Change the camera location to (0,-20, 0) and focal length to 120 mm. Render the image.

Here we change the camera location along with focal length to keep the subject the same size.

☐**Checkpoint 3: Save the rendered images under these three camera settings.**

☐**Checkpoint 4: Compare the three images in Checkpoint 3. Discuss the effect of changing the focal length.**

- Common focal lengths for real-world cameras (prime lens): 24mm, 35mm, 50mm, 85mm, 105mm.

4. Parenting Objects

First, set up the scene. Reset the rotation of the cube (put zeros into the Cube's Rotation, or use Alt/Option R). Set its location to $t_{\text{cube}} = \begin{pmatrix} 1 \\ -3 \\ 1 \end{pmatrix}$. Add a plane (menu bar Add ‣ Mesh ‣ Plane), and in the pop-up panel in the bottom left, change its size to 8 (Figure 8). The scene should look like Figure 9, with the cube sitting on top of the plane.

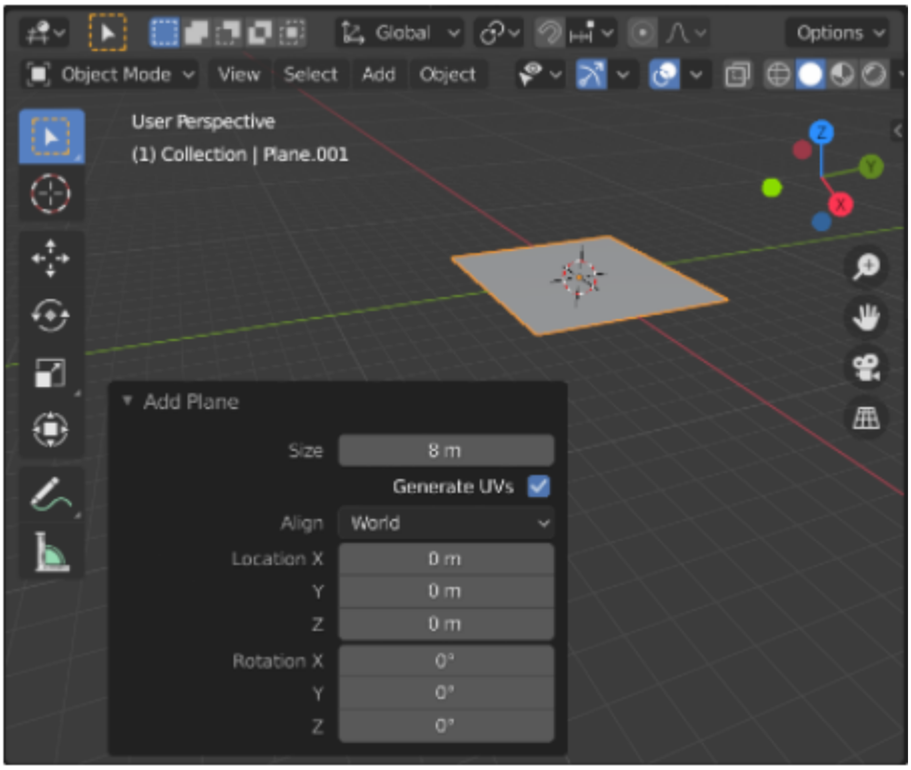


Figure 21

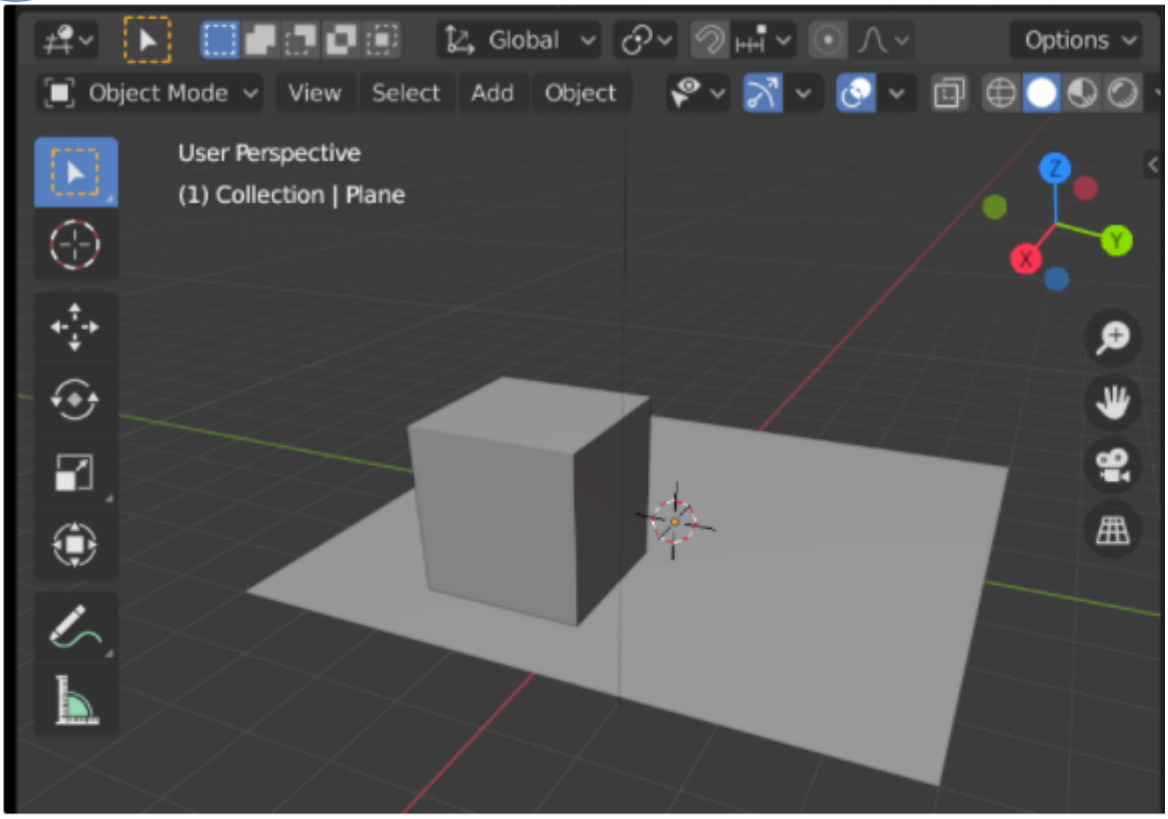


Figure 22

Next, parent the cube to the plane. Select the cube, then hold shift and select the plane. Both objects should be in an orange outline, and the plane should have a lighter orange.

To learn more about multiple selections and active objects, see [Blender Documentation].

Then go to the menu bar on top and select Object ‣ Parent ‣ Object (or leave your mouse inside the 3D viewport, and use the shortcut Ctrl/P) (Figure 10). A dotted line should appear between the origin of the cube and the origin of the plane (Figure 11), indicating an existing relationship between these two objects. You can verify this relationship by transforming the plane; the cube should follow the exact same transformation and stay on the plane.

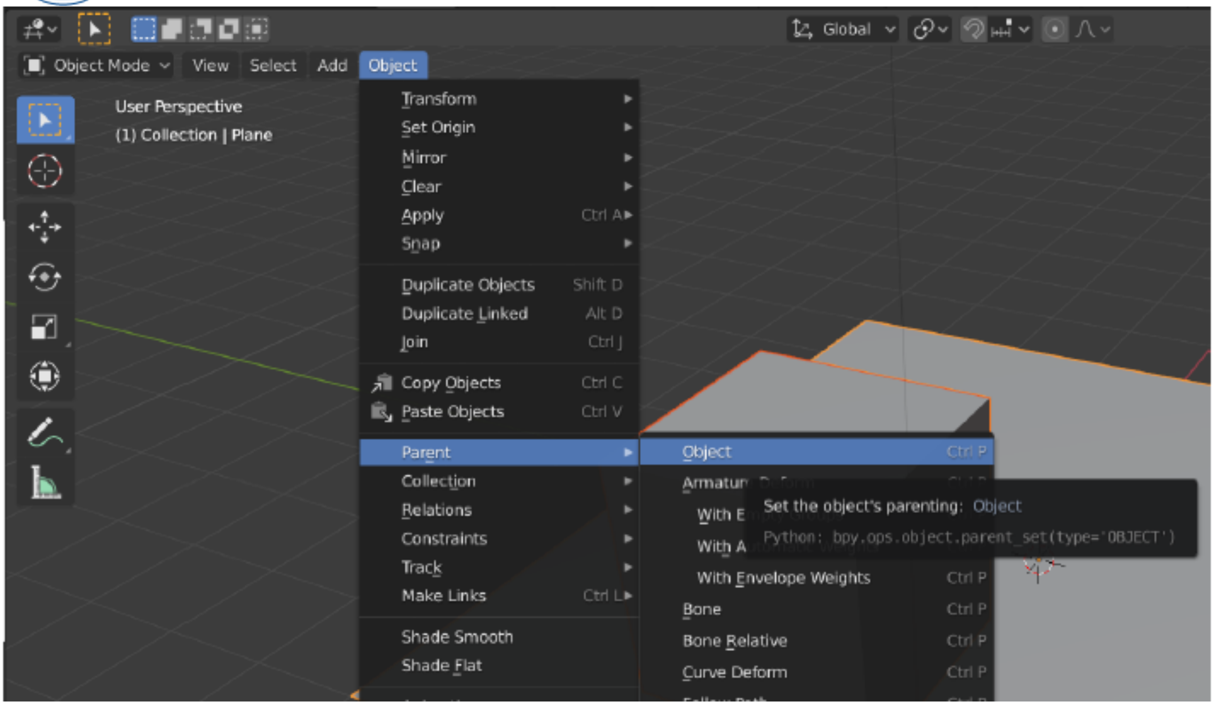


Figure 23

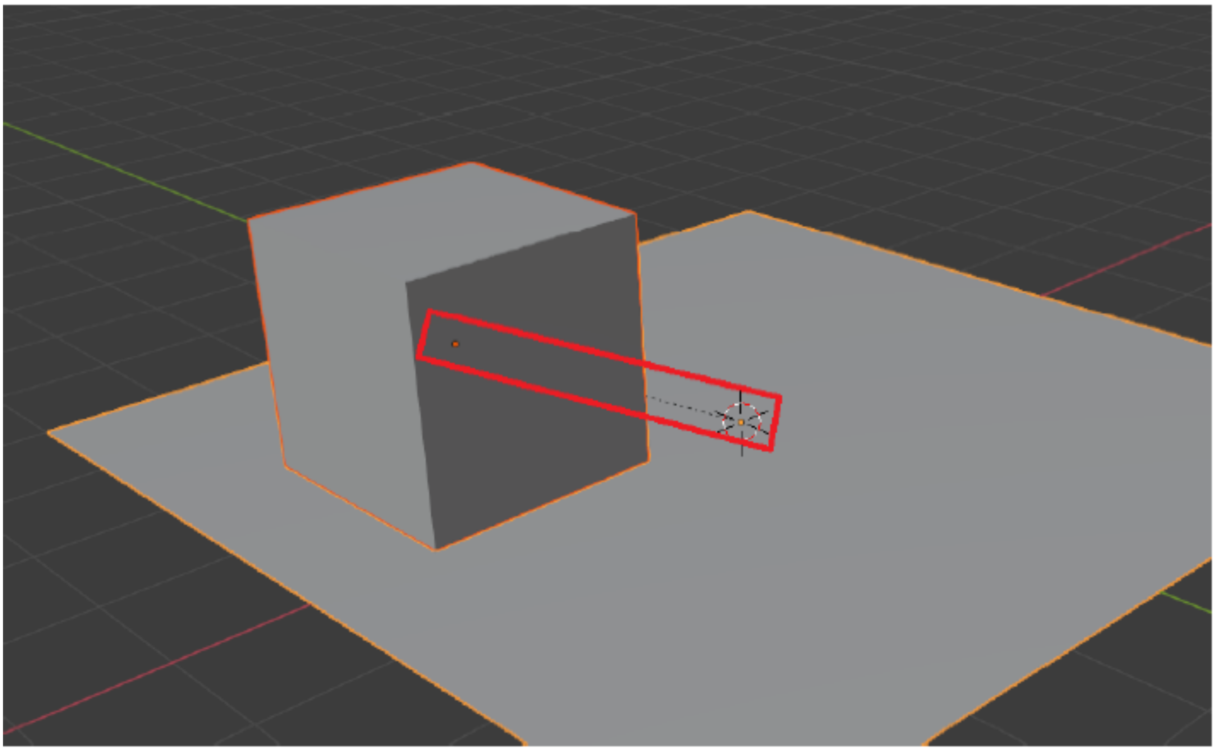


Figure 24

After parenting, the translation of the cube relative to the plane is $t_{\text{cube}}^{\text{local}} = \begin{pmatrix} 1 \\ -3 \\ 1 \end{pmatrix}$.

If we set the location of the plane to $t_{plane}{}^{world} = \begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix}$ what would the global location of the cube $t_{1\ cube}{}^{world}$ be?

If we **then** rotate the plane along its **local** X-axis by -45°, what would the global location of the cube $t_{2\ cube}{}^{world}$ be?

☐ **Checkpoint 5:Write down** $t_{1\ cube}{}^{world}$

☐ **Checkpoint 6:Write down** $t_{2\ cube}{}^{world}$

Hint:

The transform matrix for the rotated plane (ignore scaling) is:

$$\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & \sqrt{2}/2 & -\sqrt{2}/2 & 1 \\ 0 & \sqrt{2}/2 & \sqrt{2}/2 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

and the homogenous coordinate for the location of the cube is:

$$\begin{bmatrix} 1 \\ -3 \\ 1 \\ 1 \end{bmatrix}$$

More Hint

You can unparent the child object to check your answer.

Go to menu Object→Parent or shortcut Alt P, then select Clear and Keep Transformation)

5. Flat Shading

- By default, the Workbench engine uses studio lighting. This assumes a pre-existing lighting environment for the scene, which enables us to better see the shape of the monkey by shading each face with its own color. We will discuss shading and lighting in future lectures. For now, we can change the settings to render the scene without any lighting and see what the render looks like.

Open a new Blender file, add at least two objects in the scene with different colors. (Detailed instructions in Lab01). Transform them so they do not overlap while still being visible through the camera.

Change the lighting of Workbench to flat lighting (Figure 12). Render the image.

☐ **Checkpoint 7: Save the image with flat lighting.**

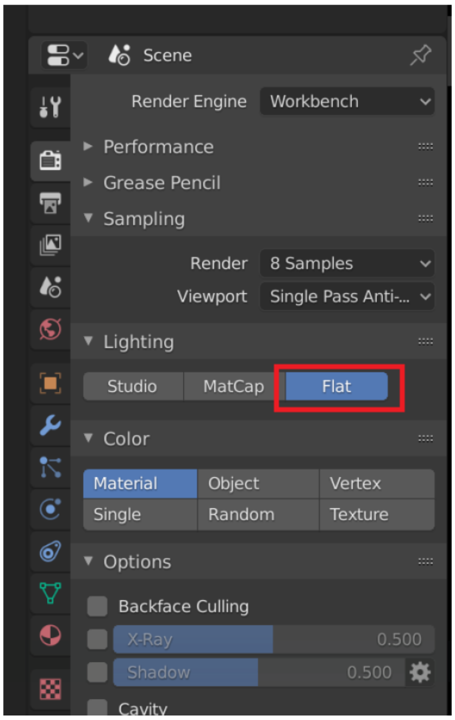
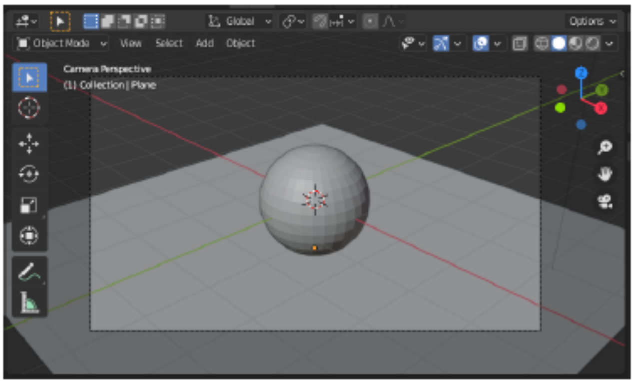


Figure 25

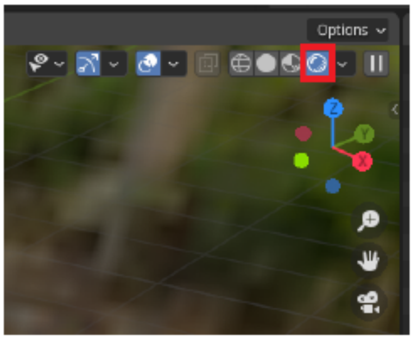
6. Lighting

Open Blender and create a new blender file, delete the default cube. Keep and the point light. Add a UV sphere. As a plane, scale it 5 times (shortcut S,5), then move it down along the z-axis by -1 (shortcut G,Z,-1)

Go to Properties Editor → Render Properties, and set Render Engine to Cycles. To preview your render, set your viewpoint shading to Rendered.



Scene setup.



Viewport Shading: Rendered.

- For this part, keep the Resolution at 1920x1080 and Percentage at 50% in the Output Properties.

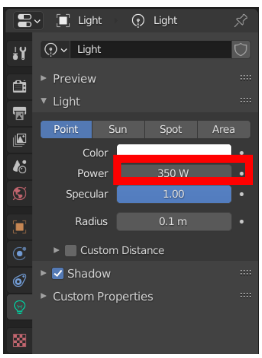
☐**Checkpoint 8: Render the image.**

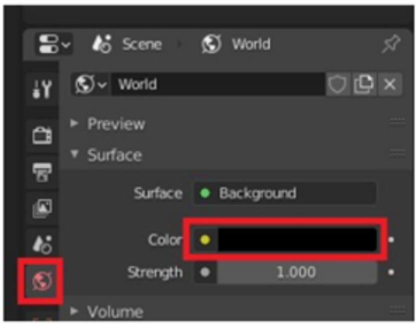
The irradiance of light depends on its distance to the object, as well as its power. Here we will change the powerand position of the light to see their relationship.

First, turn off the environment light. In Properties Editor → World Properties, set Color to black.Rendered the image. The background should be completely black.

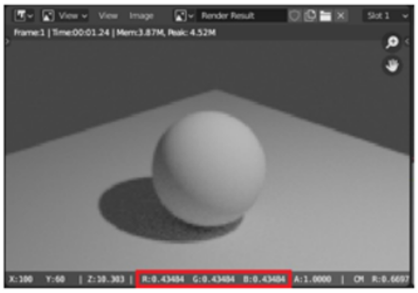
Then, we will change the power of our light. Select the light in the scene, go to Properties Editor → Object Data Properties, and change the Power to 350 W.

Switch to another slot to render the new image. This way you can then toggle between this render, and right-click on the render result and view the pixel value on the bottom. This is the raw valuebefore view transform, so it is normal for the values to exceed 1.





Set world background to black.



View pixel value.

☐**Checkpoint 8.1: Render the image with lower light power.**

Pick a pixel in the same location from both renders (the X and Y value should be the same), write down their RGB values, and find their relationship.

☐Checkpoint 8.2 : Compare the rendered checkpoint 8 with 8.1 State the relationship between light power and irradiance.

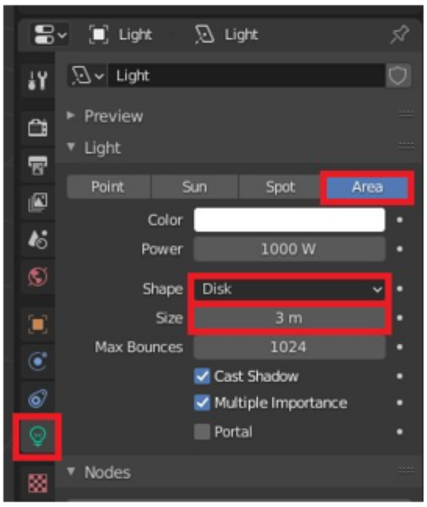
Next, we will change the distance between the object and the light. We do this by scaling the light origin closer to the sphere.

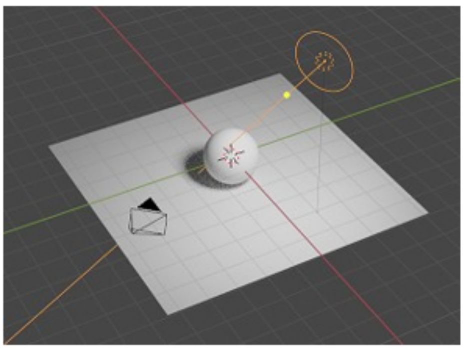
Change the light power back to 1200W.

6.1. Light Types

The previous images were rendered with the default point light. Now we will change it to an area light and compare them.

Select the light in the scene. Go to Properties Editor → Object Data Properties. Change its type to Area, Shape toDisk, and Size to 4m. You will see the wire frame of the light from the viewport.





Viewport preview with area light.

☐ Checkpoint 8.3: Render the image with the area light(disk).

Select the light in the scene. Go to Properties Editor → Object Data Properties. Change its type to Area, Shape to Square, and Size to 15m. You will see the wire frame of the light from the viewport.

☐ **Checkpoint 8.4: Render the image with the area light(square).**

Select the light in the scene. Go to Properties Editor → Object Data Properties. Change its type to Spot, Radius to 8.0 m, and Power to 700W.

☐ **Checkpoint 8.5: Render the image with the spot light.**

☐ **Checkpoint 8.6: Compare Checkpoint 8, Checkpoint 8.3, Checkpoint 8.4 and**

PROJECT REPORT SUBMISSION

!!IMPORTANT!!

This lab report is due by 23:59 on Friday, 3 November 2023.

Please write the answers in your report as follows (e.g. part1.a, part2.k)

PART 1 (25 Points)

Please follow the instruction and prepare a pdf file that includes these points:

a) Rendered Image with 1920x1080.
b) Rendered Image with 160x90.
c) Rendered Image with 3840x2160.
d) Compare the images that are 1920x1080, 160x90 and 3840x2160. Write the effect of changing the resolution.
e) Rendered Image with gamma 1.
f) Rendered Image with gamma 3.
g) Rendered Image with gamma 5.
h) Compare the images that have gamma value 1,3 and 5. Write the effect of changing the gamma value.
i) Answer this question and write your document, What's the advantage of using YUV color space?

PART 2 (45 points)

a) Write down p_{xy}
b) Write down p_{yx}
c) Explain how you get these results.
d) Write down $t_{1\ cube}^{\ world}$
e) Write down $t_{2\ cube}^{\ world}$
f) Explain how you get these results.
g) Save the rendered images under these three camera settings. (Add screenshots of them)
h) Compare the three images in Checkpoint 3. Discuss the effect of changing the focal length.
i) Save the image with flat lighting. (Add screenshots). Write the effect of flat lighting.

j) Save the rendered the image with lower light power (Add screenshots)
k) Compare the rendered checkpoint 8 with 8.1 State the relationship between light power and irradiance. Write your answer.
l) Save the rendered the images with the area light. (Add screenshots)
m) Save the rendered the image with the spot light. (Add screenshots)
n) Compare Checkpoint 8, Checkpoint 8.3, Checkpoint 8.4 and Checkpoint 8.5. Discuss how the shadow looks different between the point light, spot light and area light. Write your answer.

After finishing the project, please upload your zip folder that have your **.blend files** on the LMS. You have to upload four .blend file;

- ✓ 1st .blend file is for **1. Objects and Transforms** and **2. Order of Rotations** parts
- ✓ 2nd .blend file is for **3.Camera** part
- ✓ 3rd .blend file is for **4.Parenting Objects**
- ✓ 4th .blend file is for **5.Flat Shading**
- ✓ 5th .blend file is for **6.Lighting and 6.1. Light Types** parts

IMPORTANT: You will make 2 different submission in total. The first will be to just upload your ".blend files submission" as a zip file (project3.zip) on LMS. Secondly, you will upload your report in pdf format to the "Project3 Report Submission" part on LMS.

PART 3

- Quiz part will be **30** points.