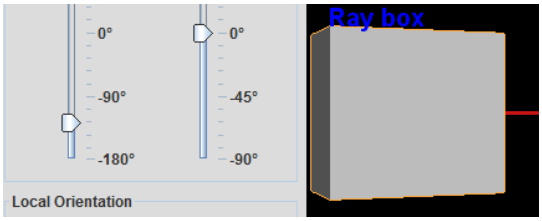
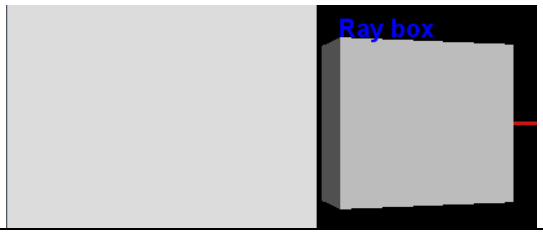
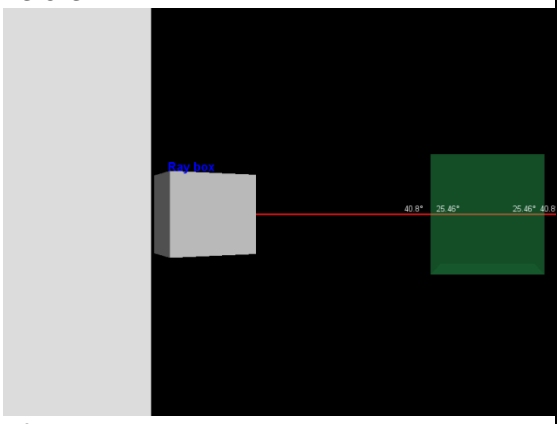
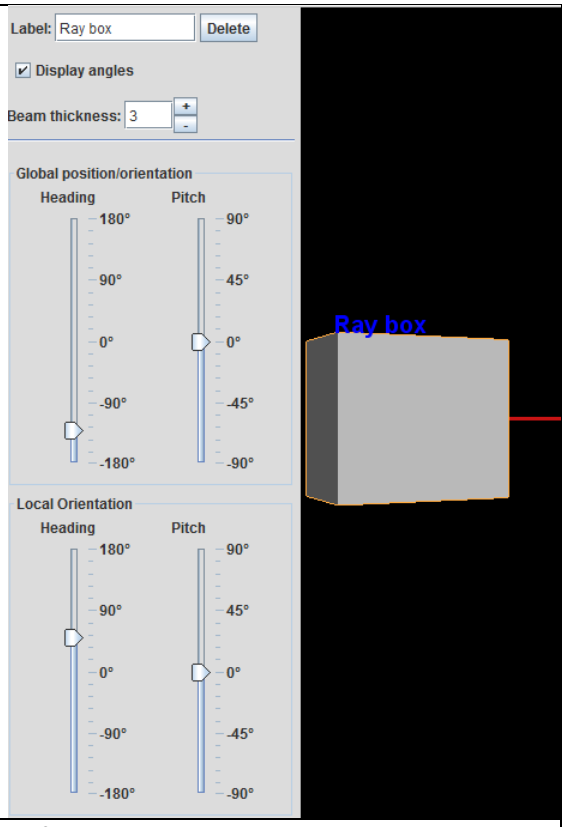
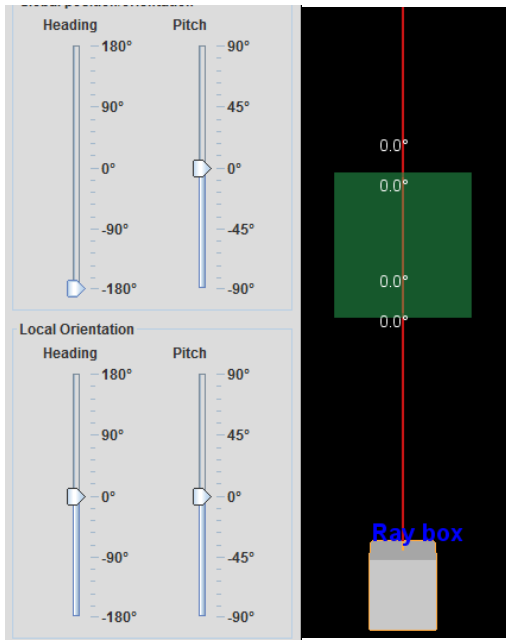
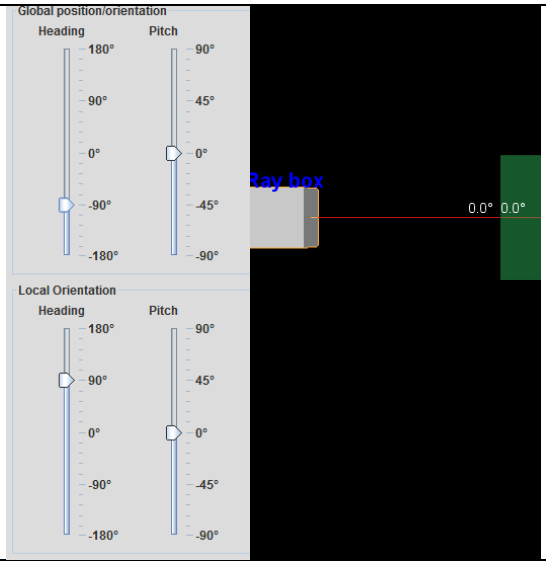
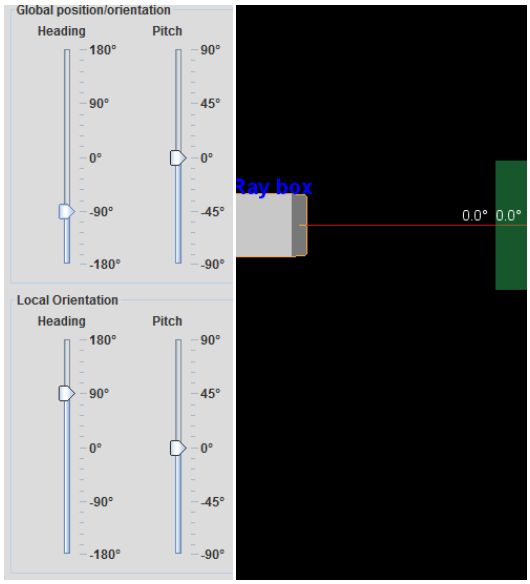
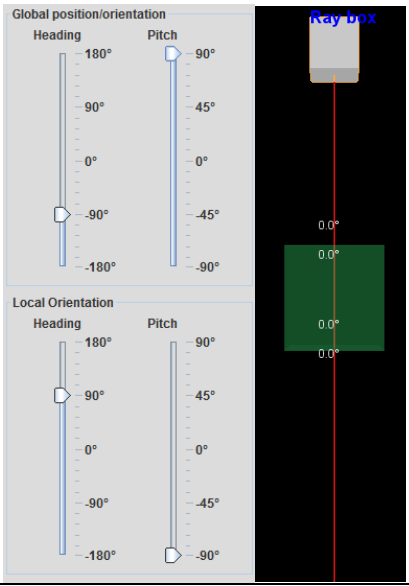
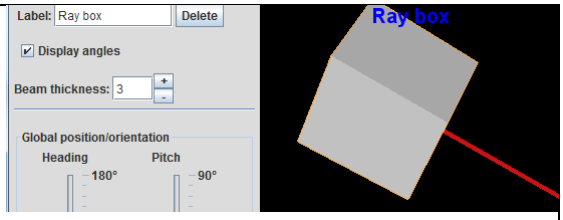
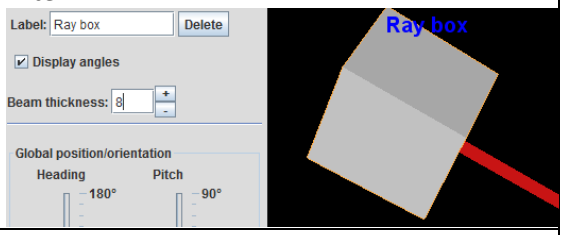
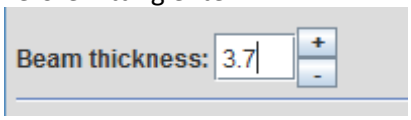
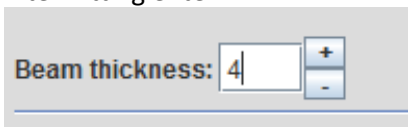
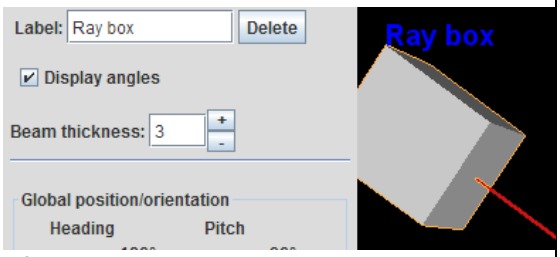
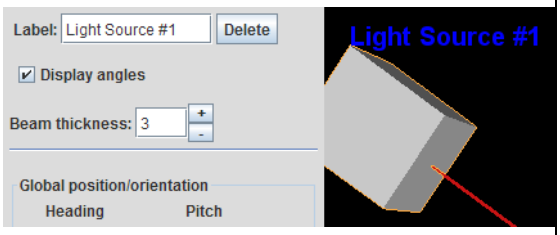
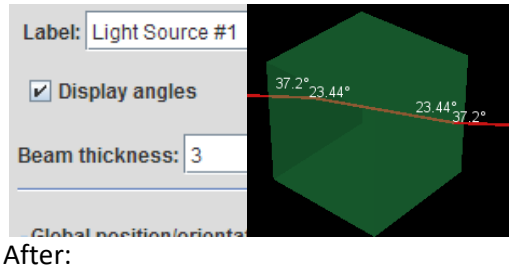
4 System Testing

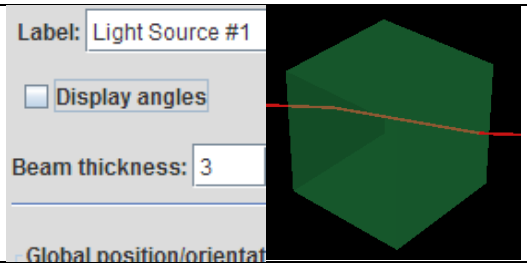
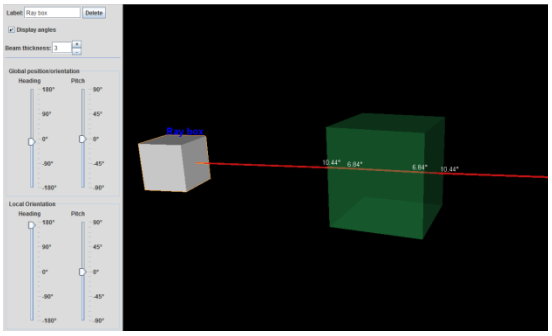
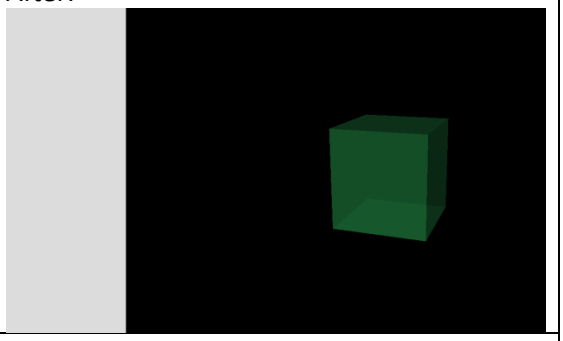
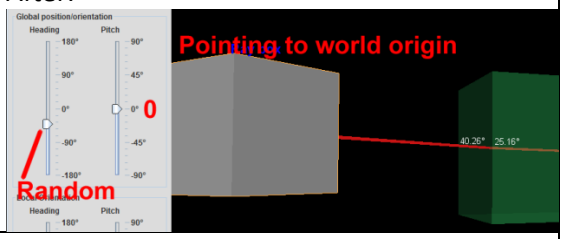
4.1 Interface Testing

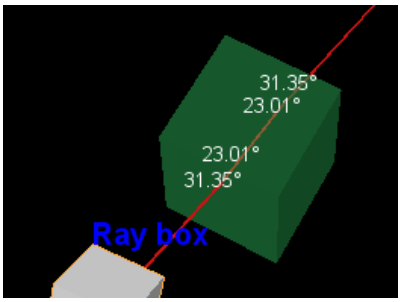
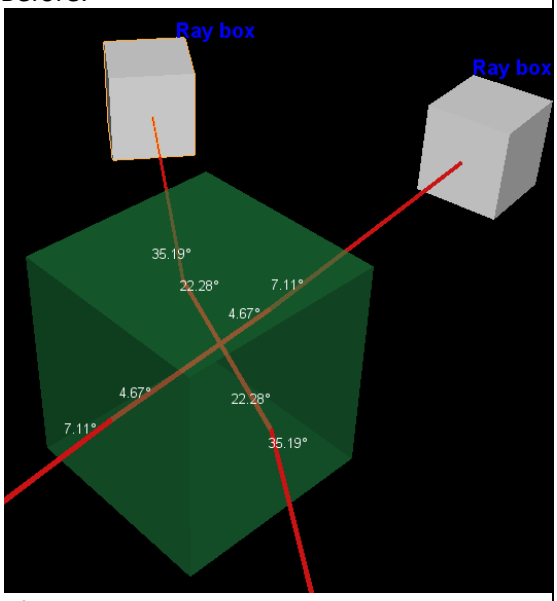
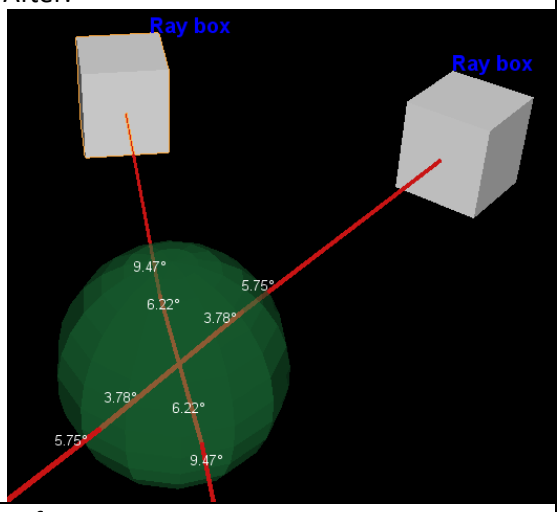
	Description	Data type	Expected result	Pass /Fail	Screenshots
1	A ray box can be deselected	Typical	Clicking in an area of the viewport where there is no ray box will remove the outline around the selected ray box and the properties panel will become blank	Pass	Before:  After: 
2	A ray box can be selected	Typical	Clicking a ray box in the viewport will draw an outline around it and the properties panel will update with the correct properties of the ray box	Pass	Before:  After:

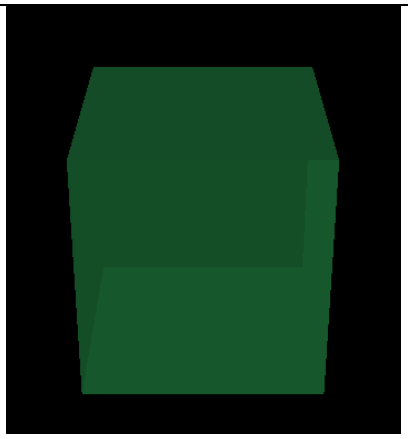
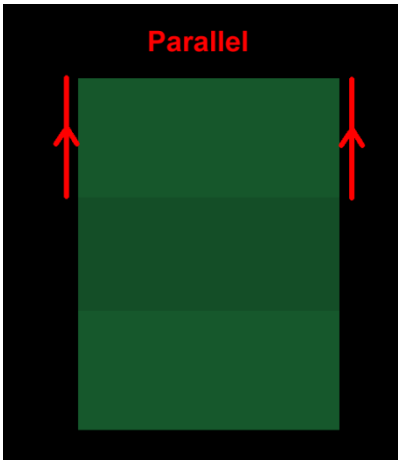
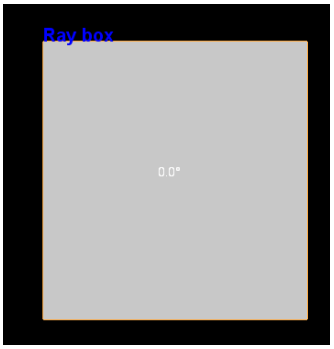
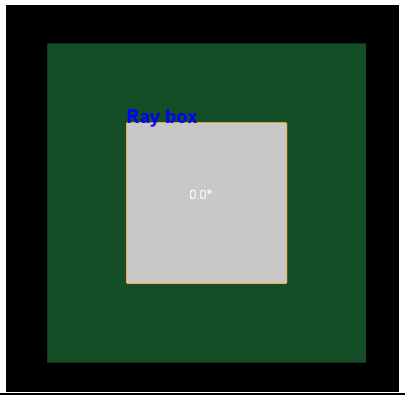
					
3	Global heading slider functions correctly	Typical	When the global heading slider is moved from $-180°$ to $-90°$, the ray box moves $90°$ clockwise around the target and the local heading slider increases by $90°$	Pass	Before:  After:

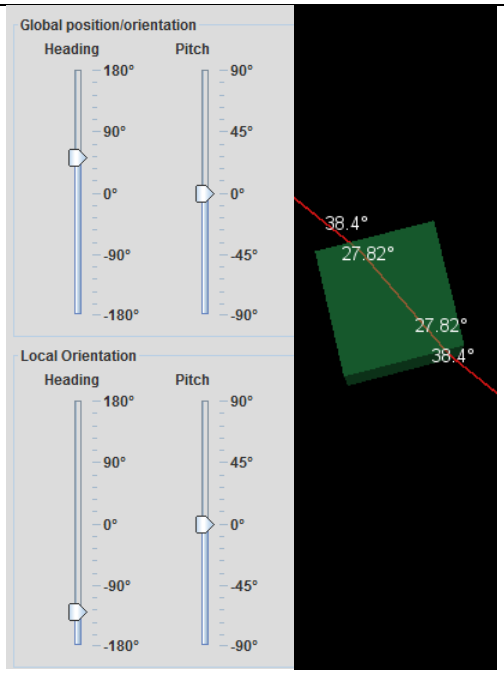
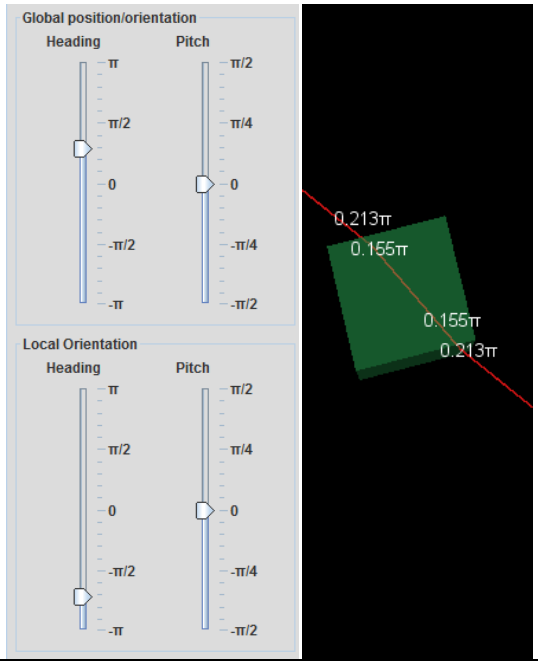
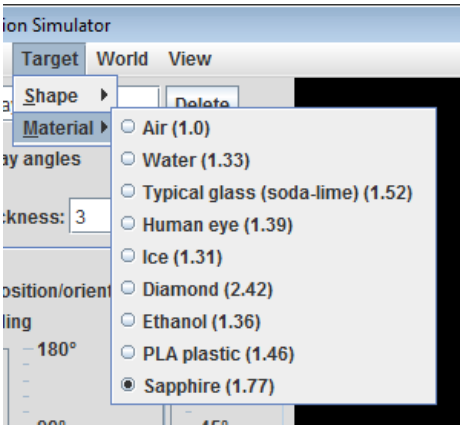
					
4	Global pitch slider functions correctly	Typical	When the global pitch slider is moved from 0° to 90°, the ray box is elevated by 90° around the target and the local pitch slider decreases by 90°	Pass	Before:  After: 
5	Changing beam	Typical	When the value of 3 is	Pass	Before:

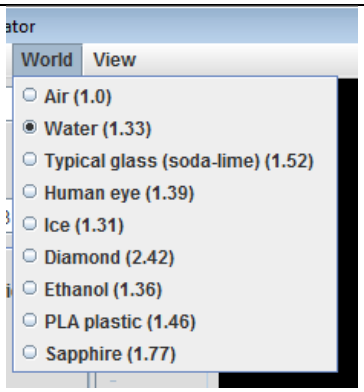
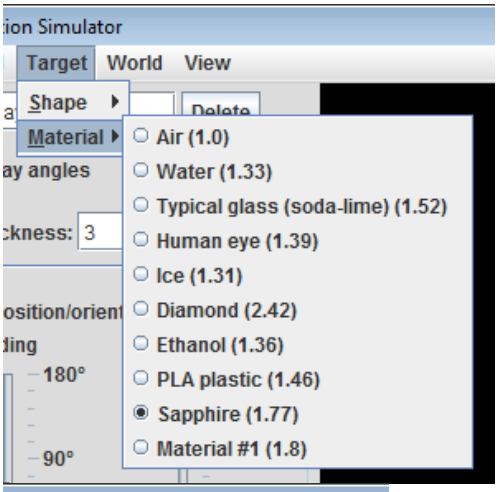
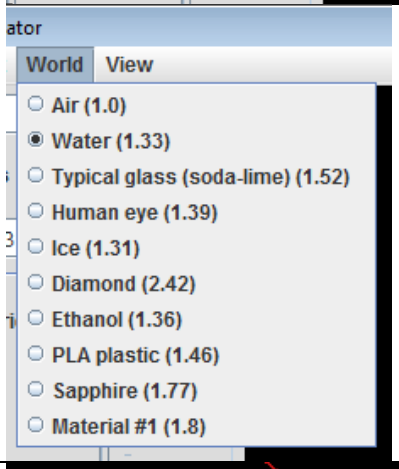
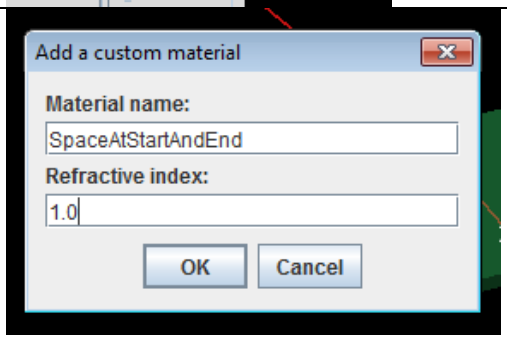
	thickness in the properties panel changes the beam's thickness in the viewport		changed to 8 and enter is hit, the beam for the selected ray box becomes thicker		 After: 
6	Beam thicknesses must be integers	Erroneous	When a beam thickness of 3.7 is typed and enter is hit, the value is rounded to 4 (the nearest integer).	Pass	Before hitting enter:  After hitting enter: 
7	Changing the label in the properties panel changes the Blue text for the selected ray box in the viewport	Typical	When the label is changed from "Ray box" to "Light Source #1" and enter is hit, the label in the viewport for the selected ray box is changed from "Ray box" to "Light Source #1"	Pass	Before:  After: 
8	Angles are not displayed for the selected ray box when the "Display angles" checkbox is	Typical	When the "Display angles" checkbox is changed from checked to unchecked, angles for the selected	Pass	Before:  After:

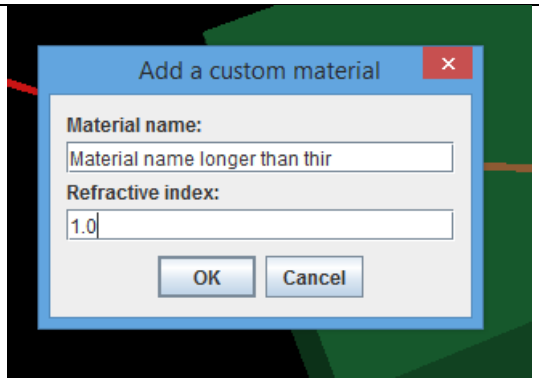
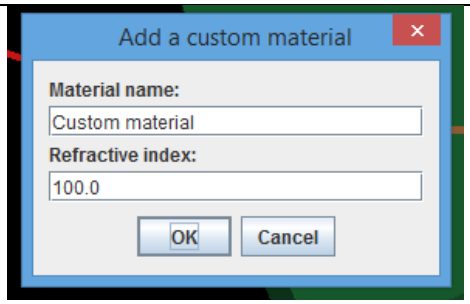
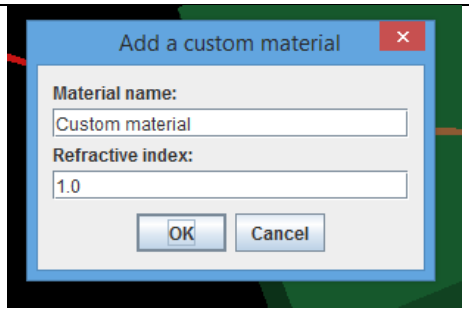
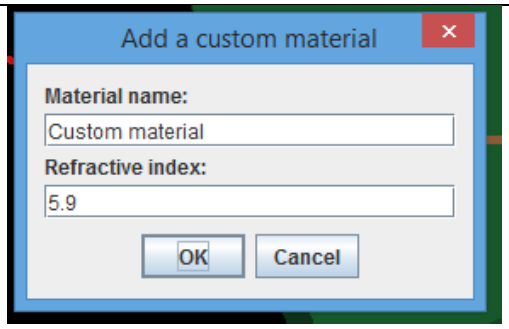
	unchecked		ray box go from visible to invisible		
9	Deleting a ray box	Typical	When the delete button is clicked the selected ray box is removed from the viewport and the properties panel cleared.	Pass	Before:  After: 
10	Adding a ray box	Typical	When Add > Ray box is clicked in the menu bar, a ray box pointing towards the world's origin with 0 global pitch and a random global heading is created and selected	Pass	Before:  After: 
11	Angles obey Snell's law	Typical	The refractive index of the final material	Pass	World has refractive index of 1.33, target has refractive index of 1.77. Target relative to world: $\frac{1.77}{1.33} = 1.3308..$

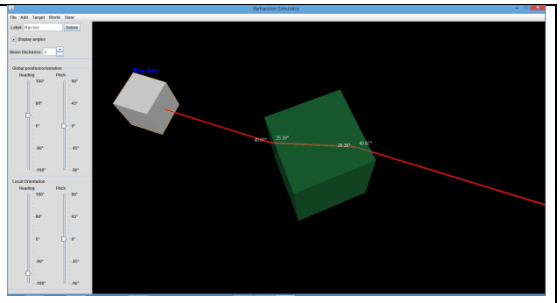
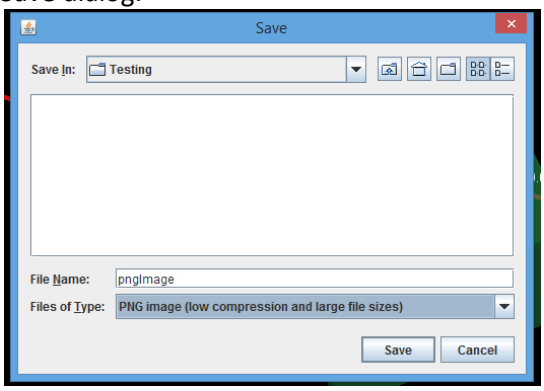
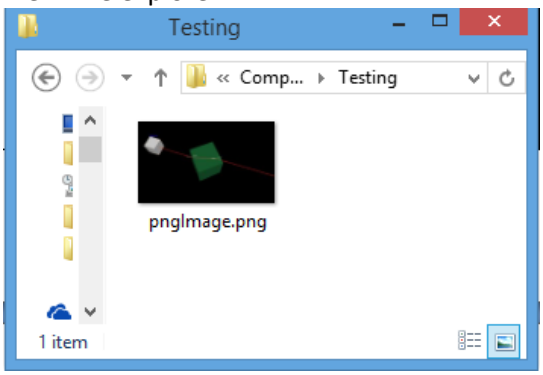
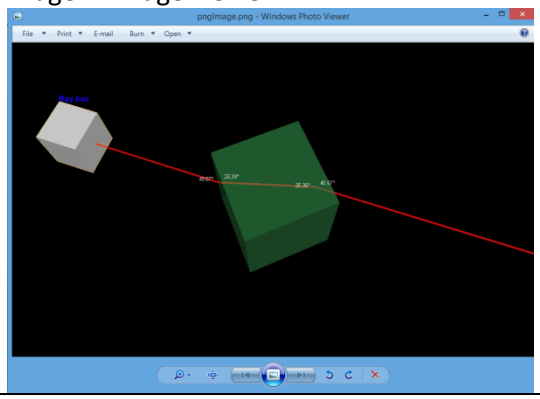
			relative to the initial material should be the sin of the angle of incidence divided by the sin of the angle of refraction		World relative to target: $\frac{1.33}{1.77} = 0.7514..$  $\frac{\sin(31.35)}{\sin(23.01)} = 1.3310..$ $\frac{\sin(23.01)}{\sin(31.35)} = 0.7513..$
12	Target object can change shape, causing all angles and beam paths to be recalculated	Typical	After starting the application, adding another ray box and clicking Target > Shape > Sphere in the menu bar should change the target from a cube to a sphere approximation and the angles and paths of beams should have been altered to reflect the change in shape	Pass	Before:  After: 
13	Orthographic projection	Typical	After pressing ‘P’ with the	Pass	Before:

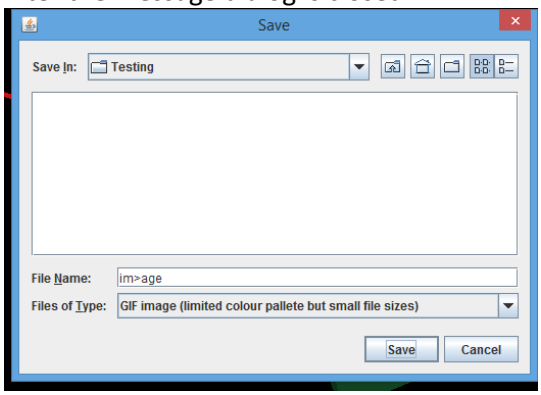
	functions correctly		viewport in focus or unchecking View > Perspective in the menu bar, parallel lines will appear parallel and objects will not become smaller as they move away.		 After:  Before:  After: 
14	Angles change to	Typical	Checking View >	Pass	Before:

	radians in the viewport and properties panel		Angles in radians will update the angles in the viewport and the labels on the sliders in the properties panel so that they are displayed in radians		 After: 
15	Custom material added to both lists in the menu bar	Typical	Clicking Add > Custom material in the menu bar and entering a material name of “Material #1” and refractive index of 1.8 will add a “Material #1	Pass	Before: 

			(1.8)" item to list under Target > Materials and the list under World		 After:  
16	Custom material name is trimmed of whitespace	Erroneous	A custom material name of " SpaceAtStart AndEnd " will be trimmed to "SpaceAtStar tAndEnd" when the text field loses focus	Pass	 Clicking back in the text field and using the arrow keys shows that there are is no whitespace at the start or end.

17	Custom material name is limited to 30 characters	Erroneous	A custom material name of “Material name longer than thirty characters” will be cut to “Material name longer than thir” when the text field loses focus	Pass	
18	Custom material refractive index range includes 100	Boundary	A custom material refractive index of 100.0 should not be altered when the text field loses focus	Pass	
19	Custom material refractive index must be greater than or equal to 1	Erroneous	A custom material refractive index of 0.5 should be changed to 1.0 when the text field loses focus	Pass	
20	Non-numerical custom material refractive indices are reverted to the last valid value	Erroneous	After entering a custom material refractive index of 5.9 and changing focus, a new refractive index of “string” should be changed to 5.9 when the text field loses focus	Pass	
21	An image of the viewport	Typical	Clicking File > Save as image in the	Pass	Application before saving:

	can be saved with the specified name in the specified directory with the specified file format		menu bar will open a dialog where the user can navigate to the “Testing” directory, enter a filename of “pngImage” and the select the png file type. Clicking the save button should then close the dialog box and create the file “pngImage.png” in the “Testing” directory. Opening the file in an image viewer should show the contents of the viewport when the image was saved.		 Save dialog:  File in file explorer:  Image in image viewer: 

22	A file cannot be saved with a name containing any of the following characters: \ / ? < > : | " % *	Erroneous	Attempting to save an image with the filename "im>age" should open a dialog box with stating that the filename contains an invalid character. Closing the message box should return the user to the save dialog with the fields populated as they were previously.	Pass	 After the message dialog is closed:  Note: the message dialog doesn't appear for filenames containing ? or *, but the files aren't saved and the save dialog remians open. Names containing / are interpreted as paths (including filenames) relative to the current directory, so don't bring up the message dialog unless they contain other invalid characters.

4.2 Hand tracing

4.2.1 Multiplying Matrices

This method belongs to the matrix class and has the intended purpose of returning the matrix for which this method has been called after it has been post-multiplied by the matrix passed as a parameter.

```
public Matrix multiply(Matrix toMultiply) {
      if (this.m != toMultiply.n) {
            throw new IllegalArgumentException("Matrices size mismatch for
multiplication");
      } else {
            Matrix result = new Matrix(toMultiply.m, this.n);
            for (int thisRow = 0; thisRow < this.n; thisRow++) {
                  for (int toMultiplyCol = 0; toMultiplyCol < toMultiply.m;
toMultiplyCol++) {
                        double sum = 0;
                        for (int thisCol = 0; thisCol < this.m; thisCol++)
{
                              sum += this.mat[thisCol][thisRow] *
toMultiply.mat[toMultiplyCol][thisCol];
                        }
                        result.mat[toMultiplyCol][thisRow] = sum;
                  }
            }
            if ((this.detKnown) && (toMultiply.detKnown)) {
                  result.det = this.det * toMultiply.det;
            } else {
                  result.detKnown = false;
            }
            return result;
      }
}
```

$Let\ \boldsymbol{A} = \begin{bmatrix} 1 & -5 \\ 3 & 0 \end{bmatrix}$

$Let\ \boldsymbol{B} = \begin{bmatrix} -2 & 6 \\ 12 & -1 \end{bmatrix}$

Initialising this in pseudocode:

```
A.mat ← [[1, 3], [-5, 0]]
A.m ← 2
A.n ← 2
A.detKnown ← false
B.mat ← [[-2, 12], [6, -1]]
B.m ← 2
B.n ← 2
B.detKnown ← false
```

Within the method, `this` refers to `A` and `toMultiply` refers to `B`.

$$\boldsymbol{AB} = \begin{bmatrix} 1(-2) - 5(12) & 1(6) - 5(-1) \\ 3(-2) + 0(12) & 3(6) + 0(-1) \end{bmatrix} = \begin{bmatrix} -62 & 11 \\ -6 & 18 \end{bmatrix}$$

Therefore, we expect `A.multiply(B)` to return a matrix with `mat` containing `[[-62, -6], [11, 18]]`.

result								thisRow	toMultiplyCol	thisCol	sum
m	n	det	detKnown	mat[0]		mat[1]					
				[0]	[1]	[0]	[1]				
2	2	0	true	0	0	0	0	0	0	-	0
										0	-2
										1	-62
				-62					1	-	0
										0	6
										1	11
						11			-	-	-
								1	0	-	0
										0	-6
										1	-6
					-6				1	-	0
										0	18
										1	18
							18		-	-	-
			false					-			

`result` is returned, so `A.multiply(B)` does indeed return a matrix with `mat` containing `[[-62, -6], [11, 18]]`.