Photography: The Big Picture

SPACE Program (14)

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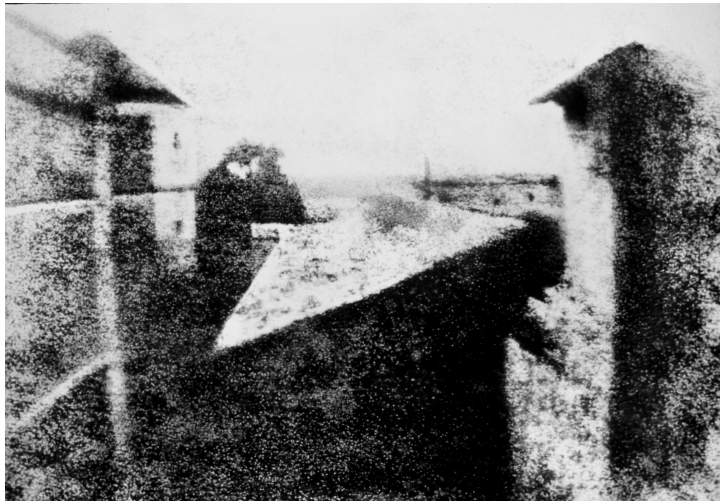
Outline

- Photography is the process of creating images by recording light using film (plastic coated with light sensitive materials) or an electronic sensor (CCD).
- From the Greek *photos-* for light and *-graphos* for drawing.
- Camera photography was invented early in the 19th century.
  - Earliest existing photo is “View from the Window at Le Gras” created by Nicèphore Nièpce in 1826.
- Initially, all photography was monochrome, until colour techniques were discovered in the late 19th century.

View from the Window at Le Gras



Early colour photograph, 1915

- The first commercially successful colour process, Autochrome, was introduced in 1907.
  - Used a mosaic of dyed potato starch grains as a filter, allowing colour components to be recorded.
- Kodachrome was introduced in 1935.
  - Used a multi layer emulsion, with each layer sensitive to a different colour.
- Digital photography was introduced in 1981 by Sony, and is continually being perfected.

Photo taken with Autochrome

Photo taken with Kodachrome

Shutter Speed

- Shutter speed is the amount of time the shutter is held open, measured in seconds.
- The standard shutter speeds are:
  1/1000 1/500 1/250 1/125 1/60 1/30 1/15 1/8 1/4 1/2 1 ...
- The scale the light reaching the film/sensor doubles with each subsequent setting.
- The general rule for reducing camera shake (without flash) is to use the shutter speed closest to the focal length of the lens being used
  - E.G., for a 50mm lens, use a shutter speed of 1/60.
- Slower shutter speeds let more light in, but capture light for a longer time.
  - Produces motion blur, which may be desirable in some situations, but is often detrimental.

Aperture

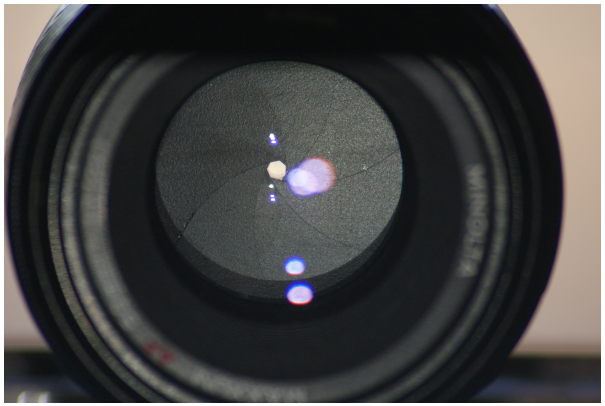
- The aperture is the opening that lets in the light.
- The ‘f’ number is used to characterize the size of the opening, and is defined as

$$N = \frac{f}{D} \tag{1}$$

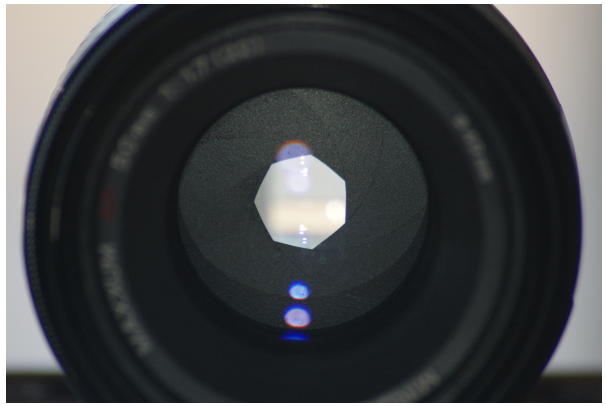
  Where D is the diameter of the opening, and f is the focal length of the lens.
- Quoted as f/N
- The greater f-number, the smaller the aperture.
- It is also known as the ‘focal ratio’ in astronomy.

- A 50mm lens with an f-number of f/5 has a diameter of 10mm, while a 100mm lens with an f-number of f/5 has a diameter of 20mm.
- Both lenses will have the same intensity of light at the focal plan.

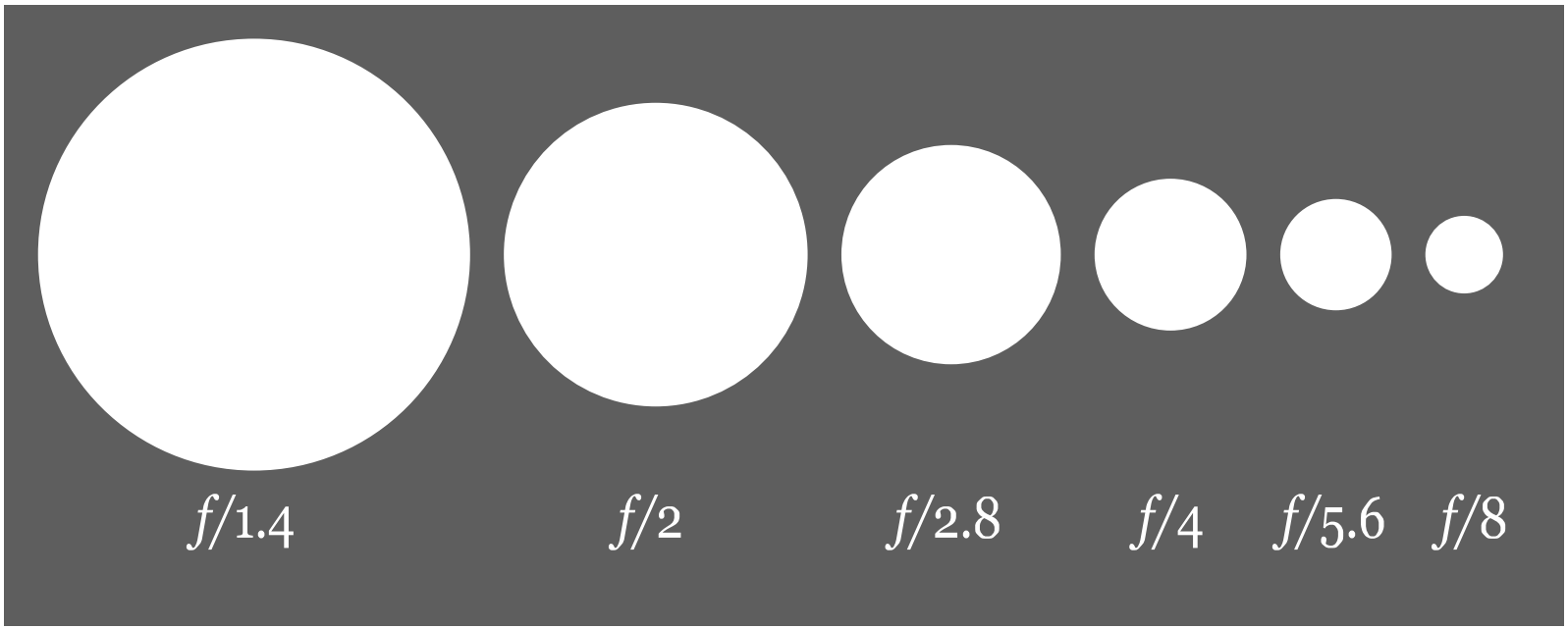
Small aperture, large f-number



Large aperture, small f-number



- f-stops are a standard set of f-numbers:
  f/1 f/1.4 f/2 f/2.8 f/4 f/5.6 f/8 f/11 f/16 f/22 ...
- Why this seemingly arbitrary set of numbers?
- Here's a visualization to help:

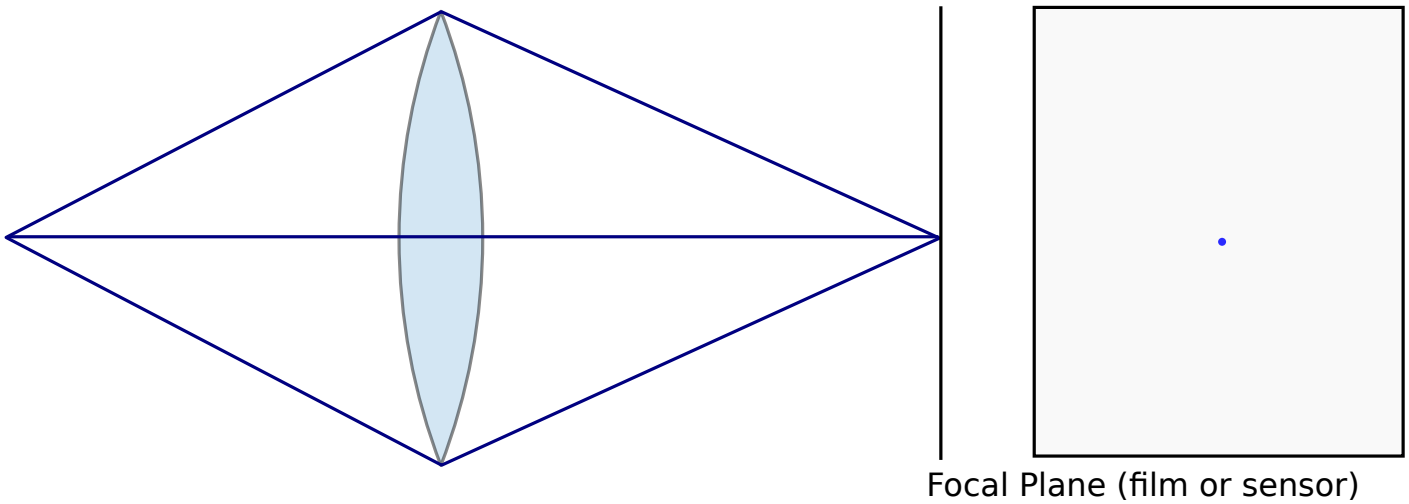


- A 100mm focal length with an f-number of 2 has an aperture diameter of 50mm and thus and an aperture area of 1,963mm^2.
- If the f-number is increased to f/2.8, the diameter of the aperture decreases to 35.7mm, and the area decreases to 1,002mm^2.
- The area of the aperture (and the amount of light that is allowed through) decreases by (roughly) half for each subsequent f-stop value.
- Each number is incremented by $\sqrt{2}$.

- The depth of field is the depth of an image which is in focus.
  - Low depth of field: only the area which is in focus is clear.
  - High depth of field: a much larger area around the focal point is clear.
- The depth of field of an image is controlled by the aperture of the lens.
  - Lower f-number produces low depth of field.
  - Higher f-number produces high depth of field.
- How does this work?

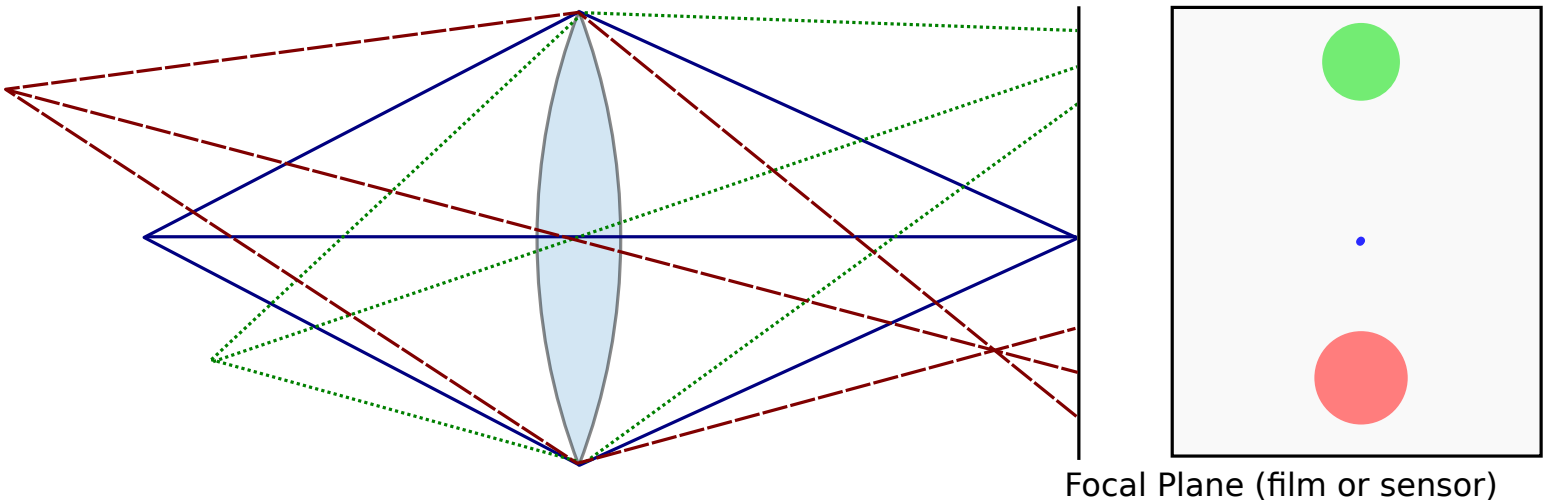
Explanation

- Object in focus produces clear image.



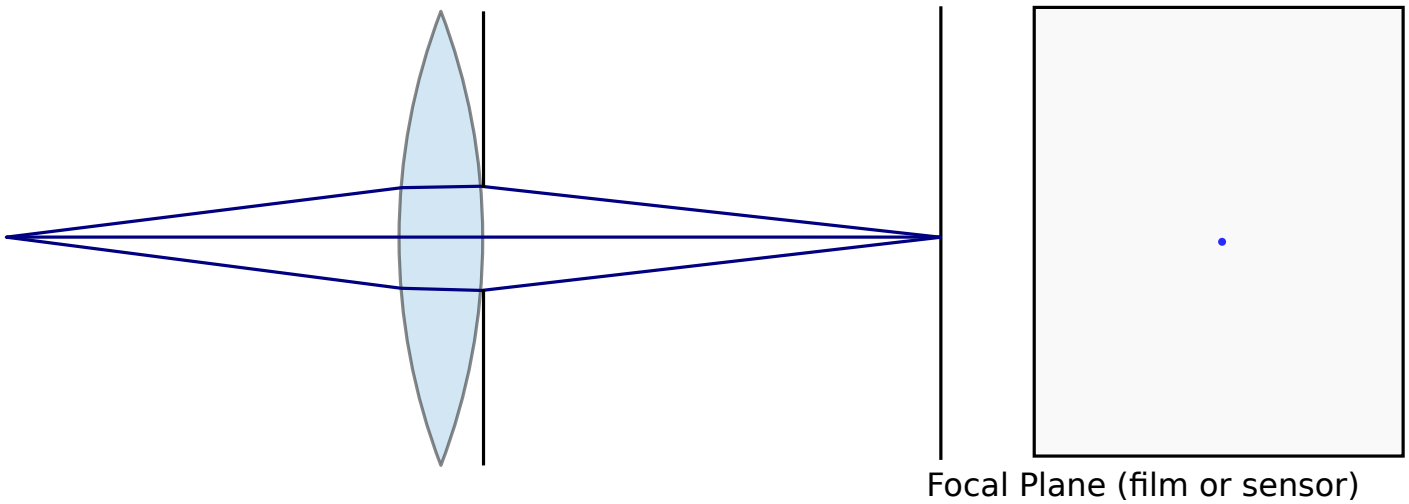
Explanation

- Object in focus produces clear image.
- Objects not in focus are smeared out over a large circle (the circle of confusion).



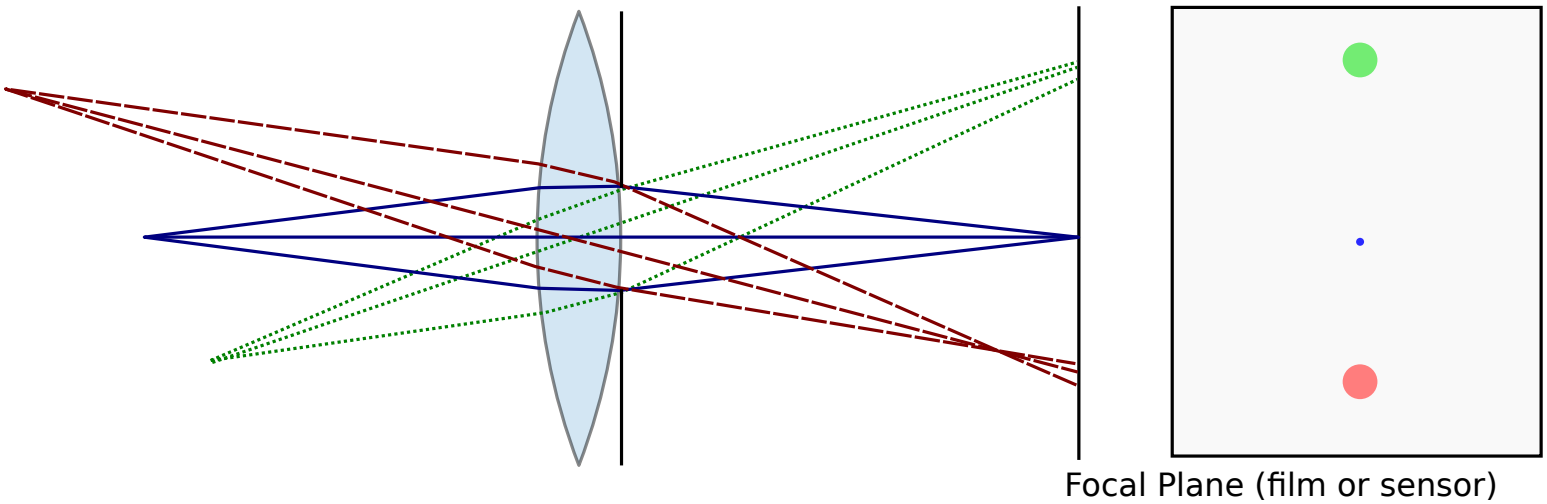
Explanation

- Object in focus produces clear image.
- Objects not in focus are smeared out over a large circle (the circle of confusion).
- Add a small aperture (large f-number).



Explanation

- Object in focus produces clear image.
- Objects not in focus are smeared out over a large circle (the circle of confusion).
- Add a small aperture (large f-number).
- Objects not in focus are smeared over a smaller circle.




f/1.7


f/2.8


f/5.6


f/11


f/22

Exposure Value

- Since the scale for f-stop and shutter speed both increase/decrease the amount of light reaching the lens by a factor of two, one can compensate for the change in one by changing the other.
  - E.G., using a shutter speed of 1/250 and an f-stop of f/5.6 will produce the same brightness as a shutter speed of 1/125 and an f-stop of f/8.
- Two quickly determine if two settings are equivalent, define the Exposure Value:

$$EV = log_2 \frac{N^2}{t} \tag{2}$$

  Where N is the f-number and t is the shutter speed.
- For the example above, the EV is 13
- An increase in EV by 1 corresponds to a reduction in light intensity by half.

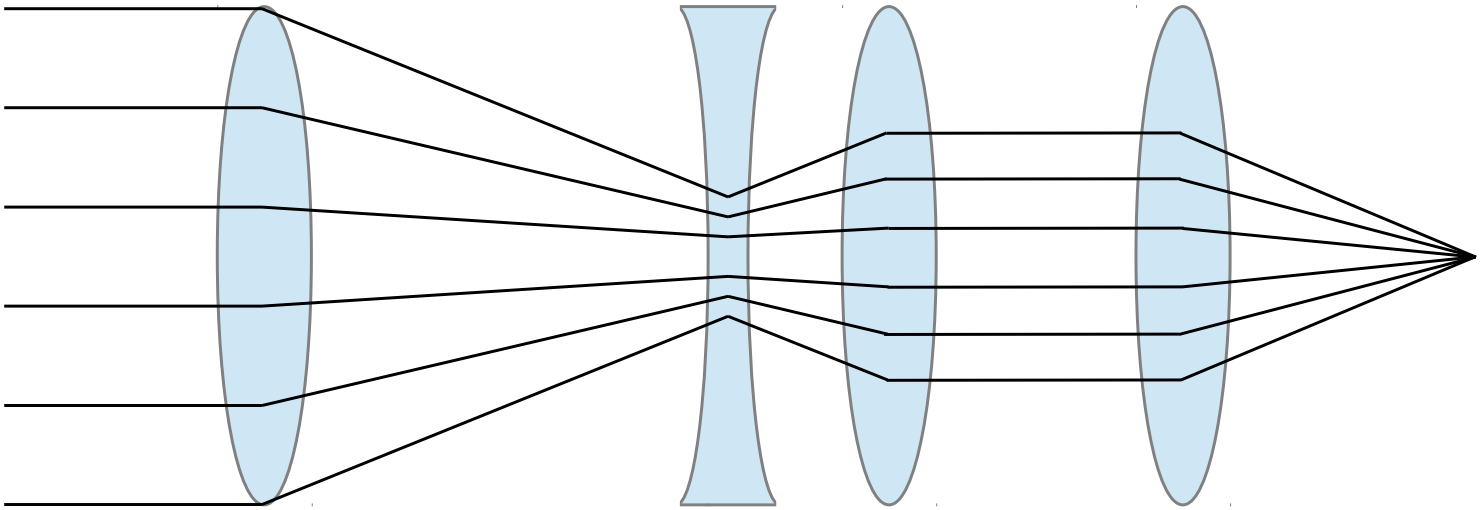
Lenses

- To get a clear image, a lens must be focused on an object.
- Recall the thin lens formula

$$\frac{1}{f} = \frac{1}{S_1} + \frac{1}{S_2} \tag{3}$$

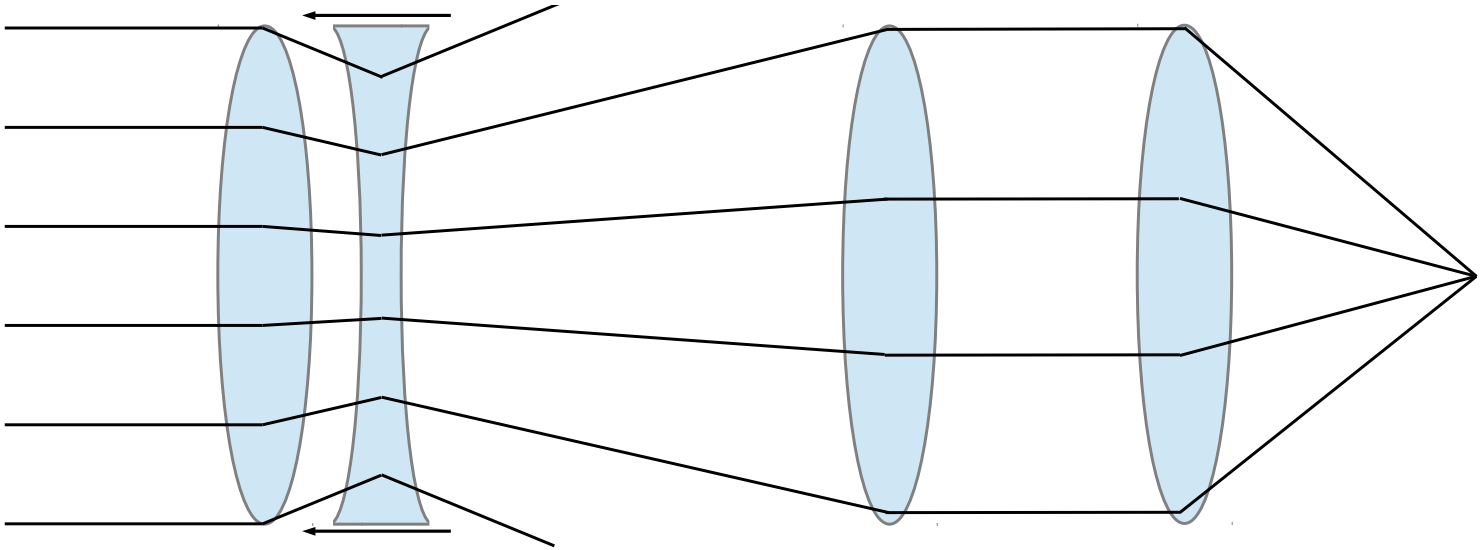
  Where f is the focal length of the lens, S_1 is the distance between the object and the lens, and S_2 is the distance between the image and the lens
- In order to focus on some object, the lens must be able to move within its housing

- A simplified zoom lens system consists of a pair of convex lenses with a concave lens between them, and a focusing element.
- For wide angle shots, the concave lens sits near the rear convex lens.
  - Light entering the forward lens is narrowed, decreasing the magnification.
  - A wide area is captured by the film/sensor.

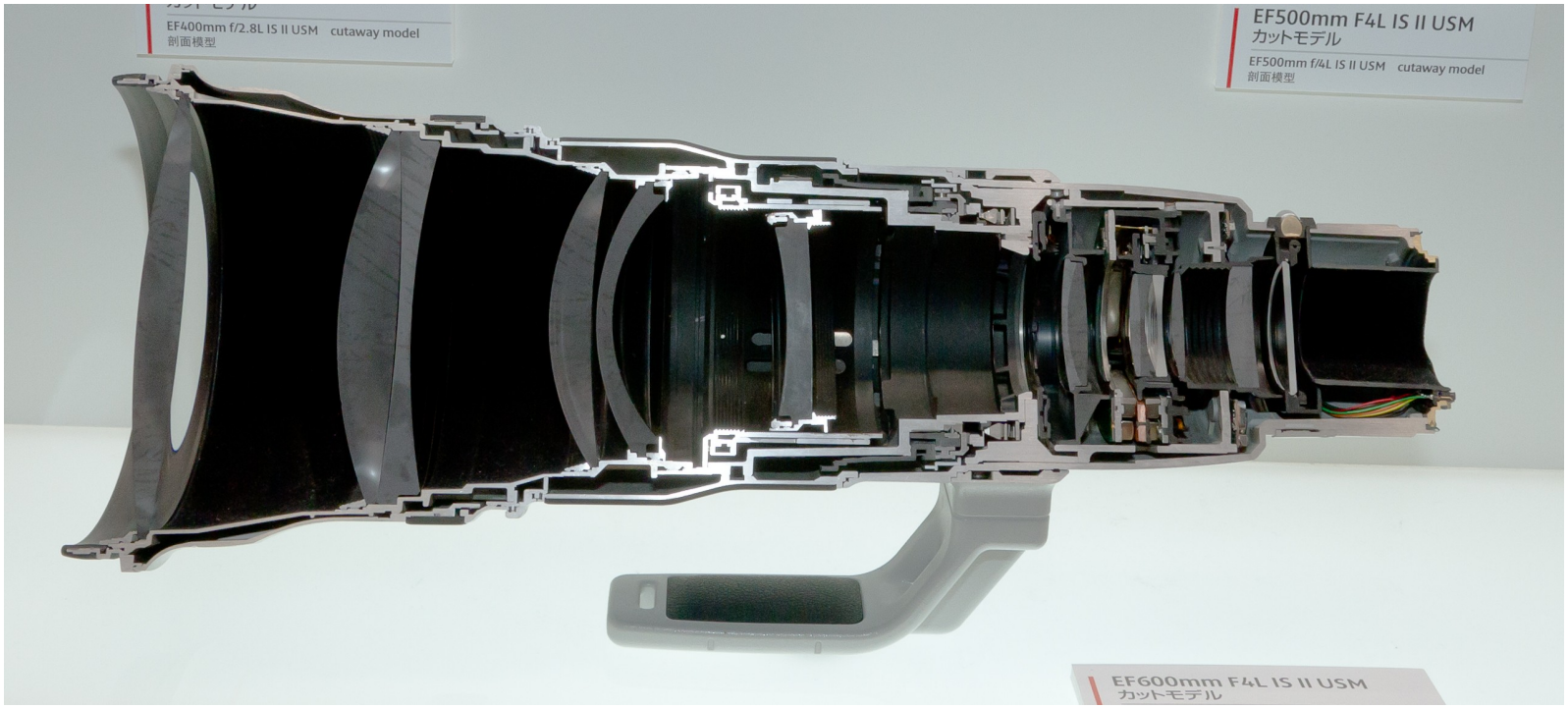


Zoom

- A simplified zoom lens system consists of a pair of convex lenses with a concave lens between them, and a focusing element.
- For telephoto shots, the concave lens is moved forward.
  - Light entering the forward lens is dispersed, increasing the magnification.
  - Only the center area is captured by the film/sensor.

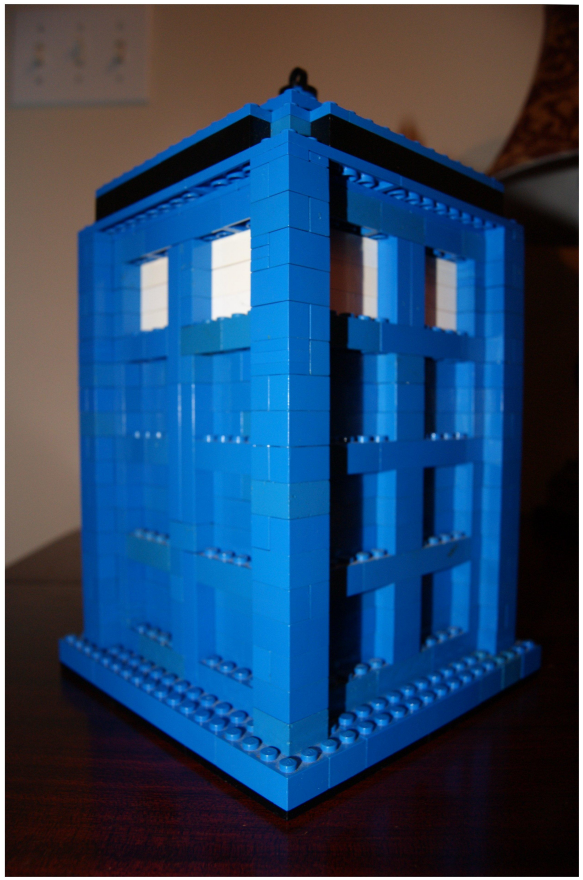


- In practice, zoom lenses are a lot more complicated, being comprised of several lens groups, some of which move and some which don't.
- Canon EF600mm F4L IS II cutaway:

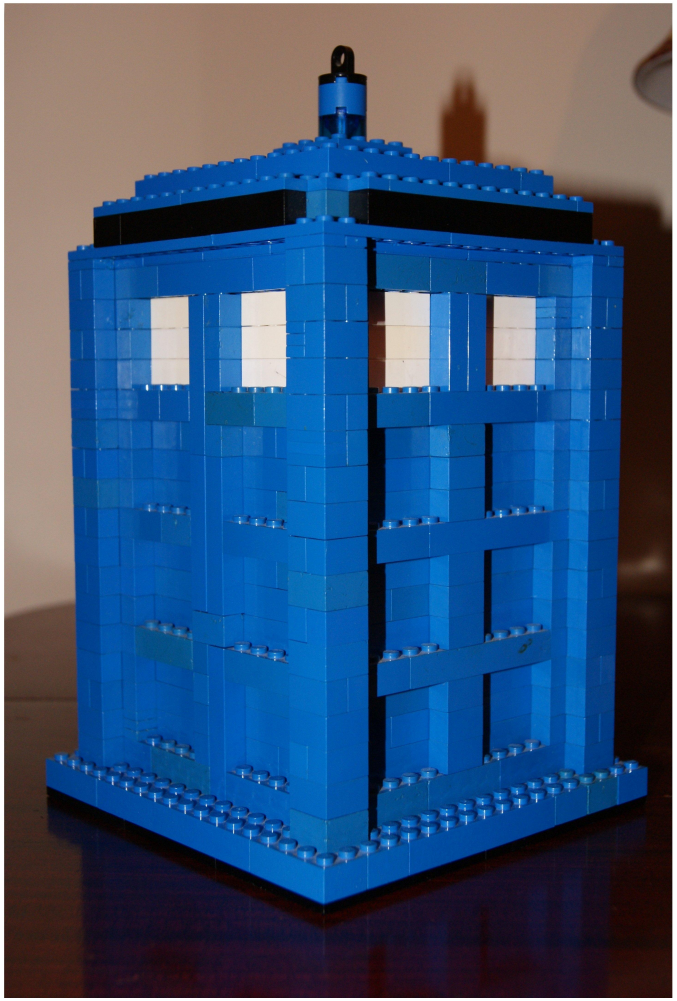


- The next series of photos shows the same object at roughly the same size.
- What is going on here?

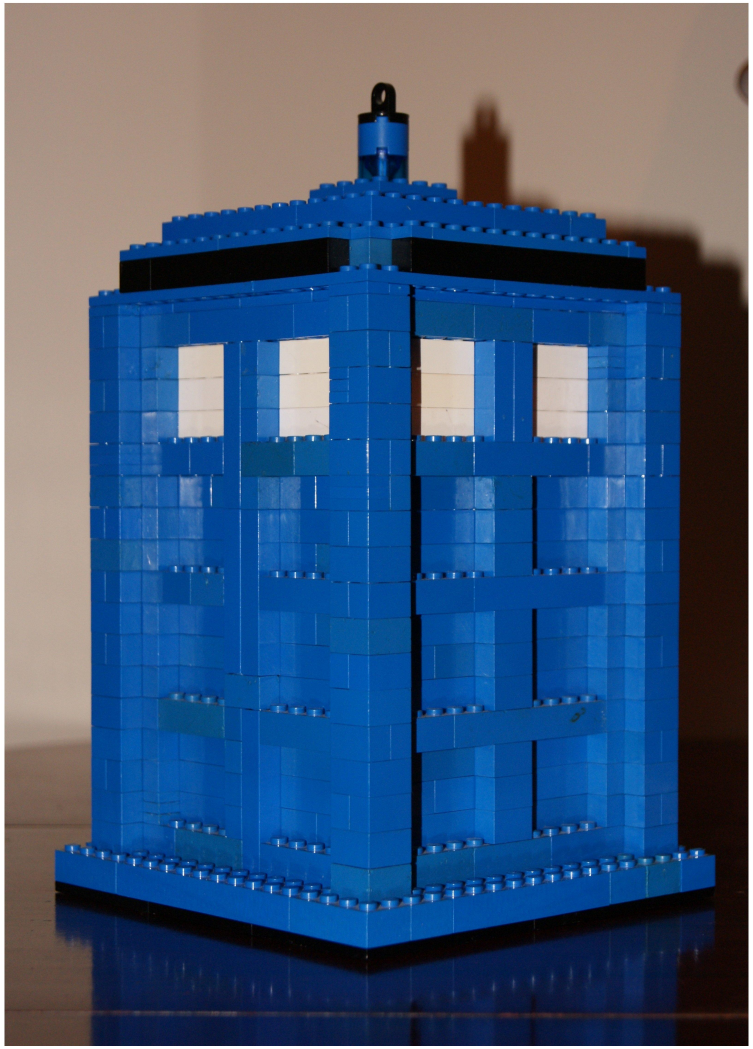
Perspective Distortion



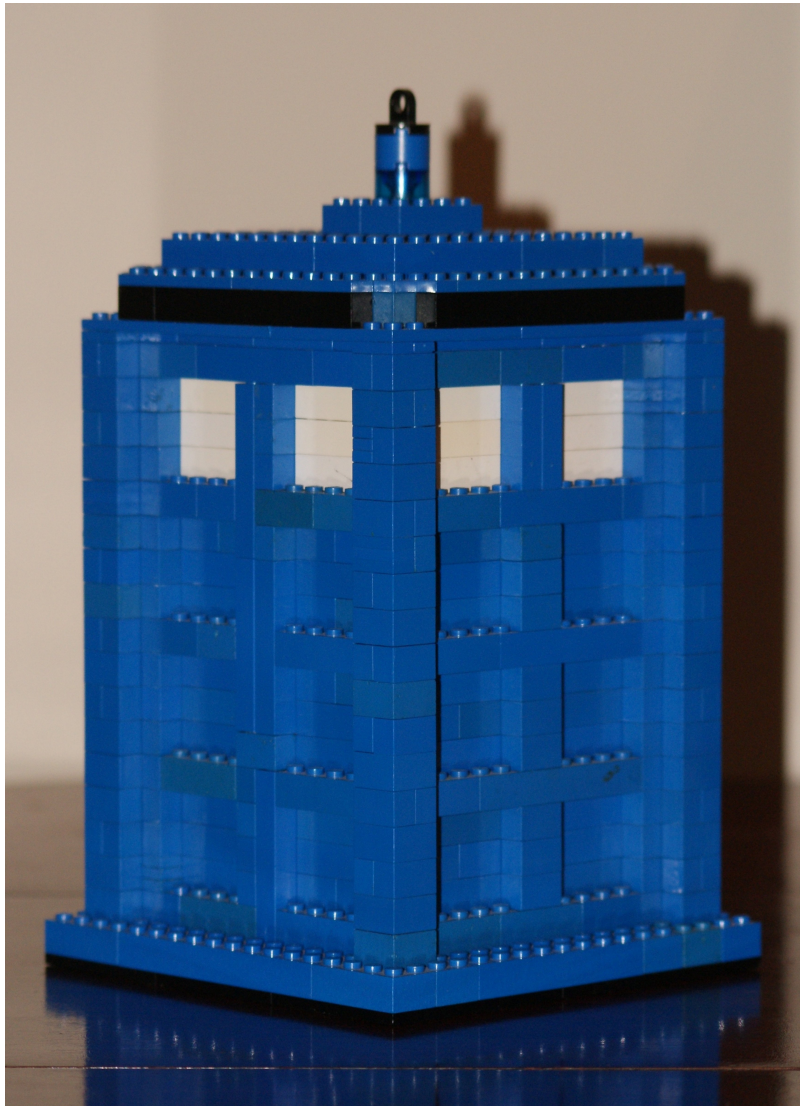
Perspective Distortion



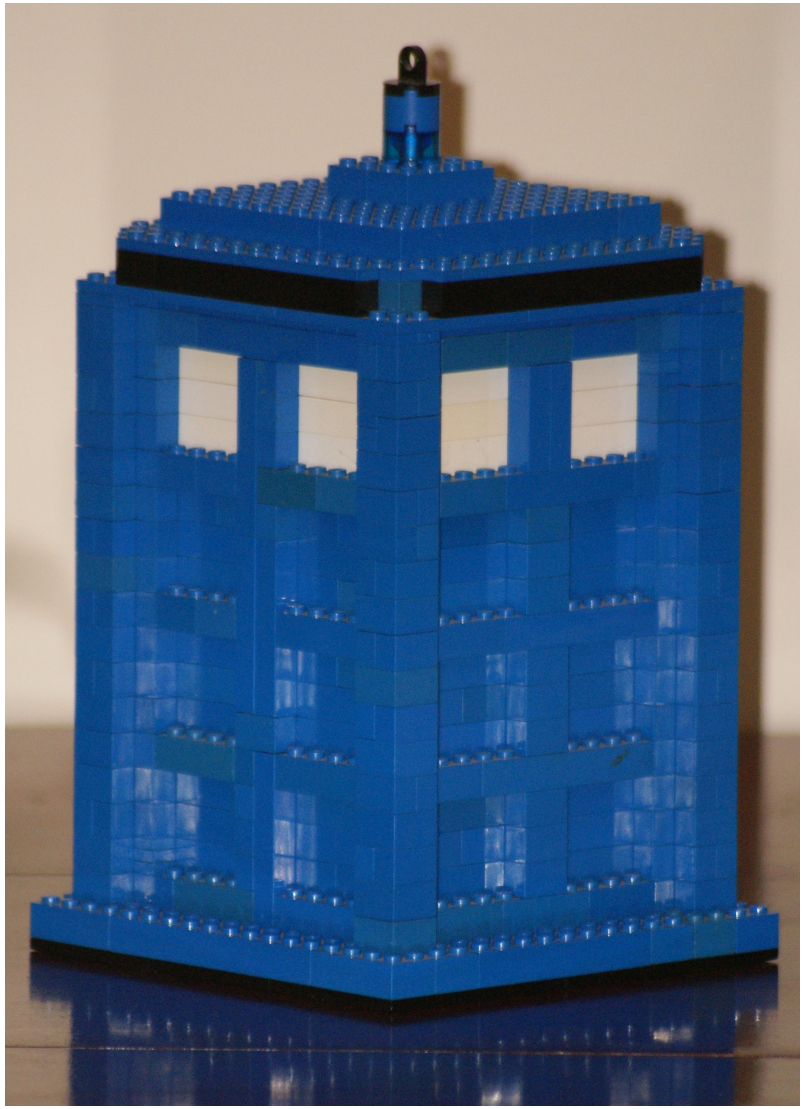
Perspective Distortion



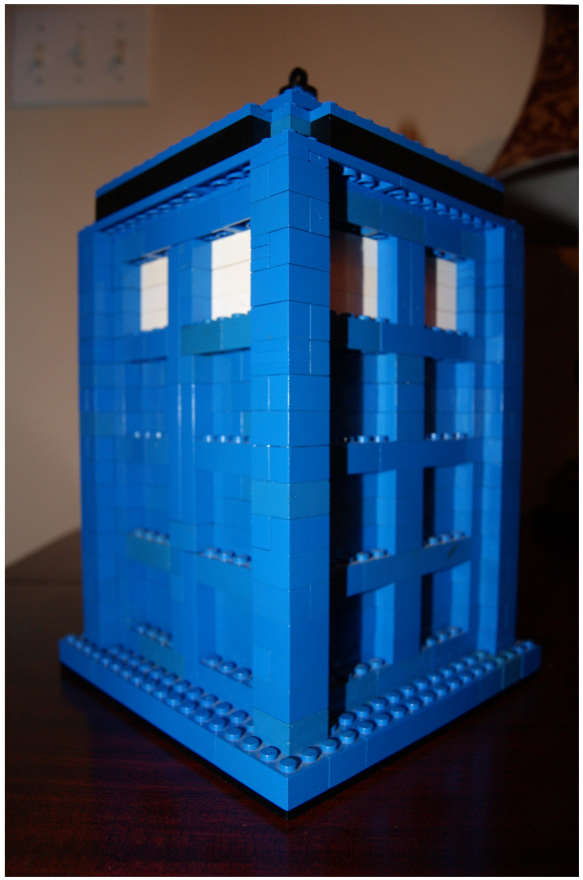
Perspective Distortion



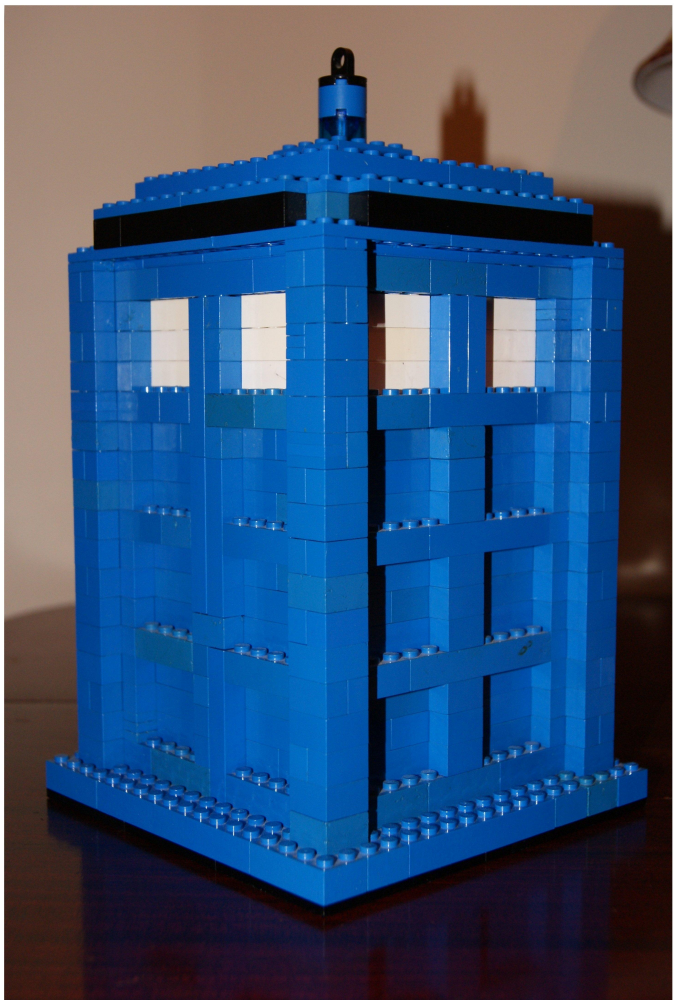
Perspective Distortion



- Each of the photos are taken with a different focal length and a different distance from the lens
- Let's see them again, with the focal length and object distance included.



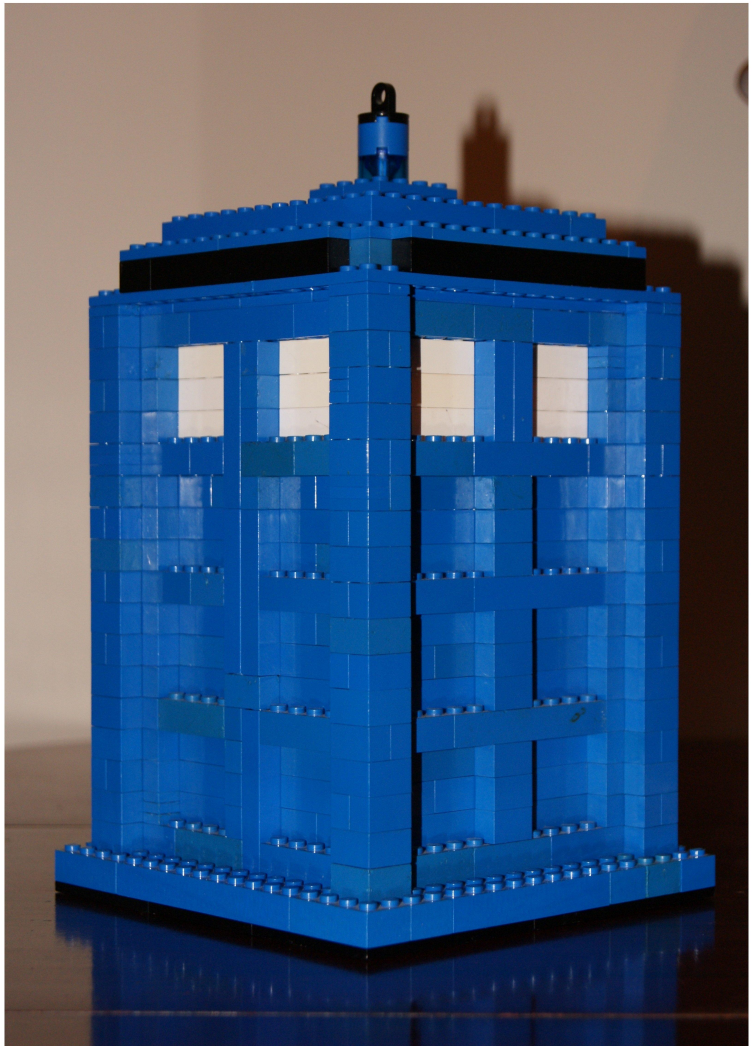
Focal length: 18mm
Distance: ∼20cm



Focal length: 30mm

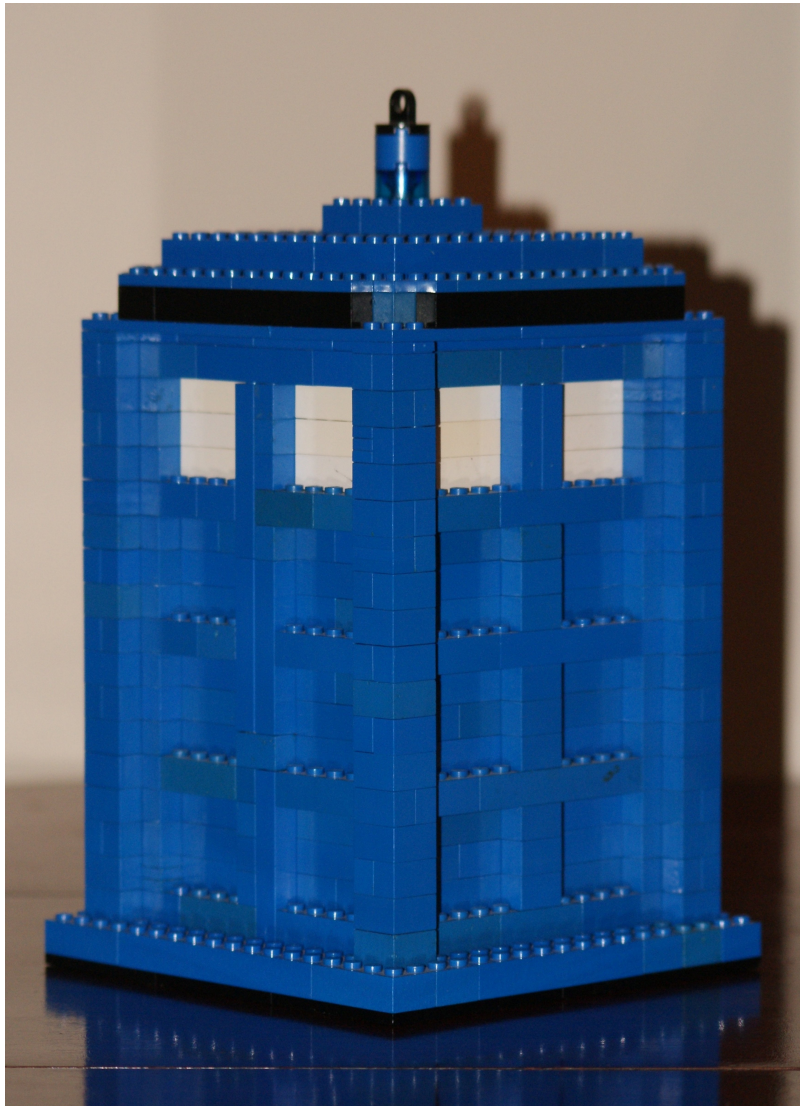
Distance: $\sim$40cm

Perspective Distortion



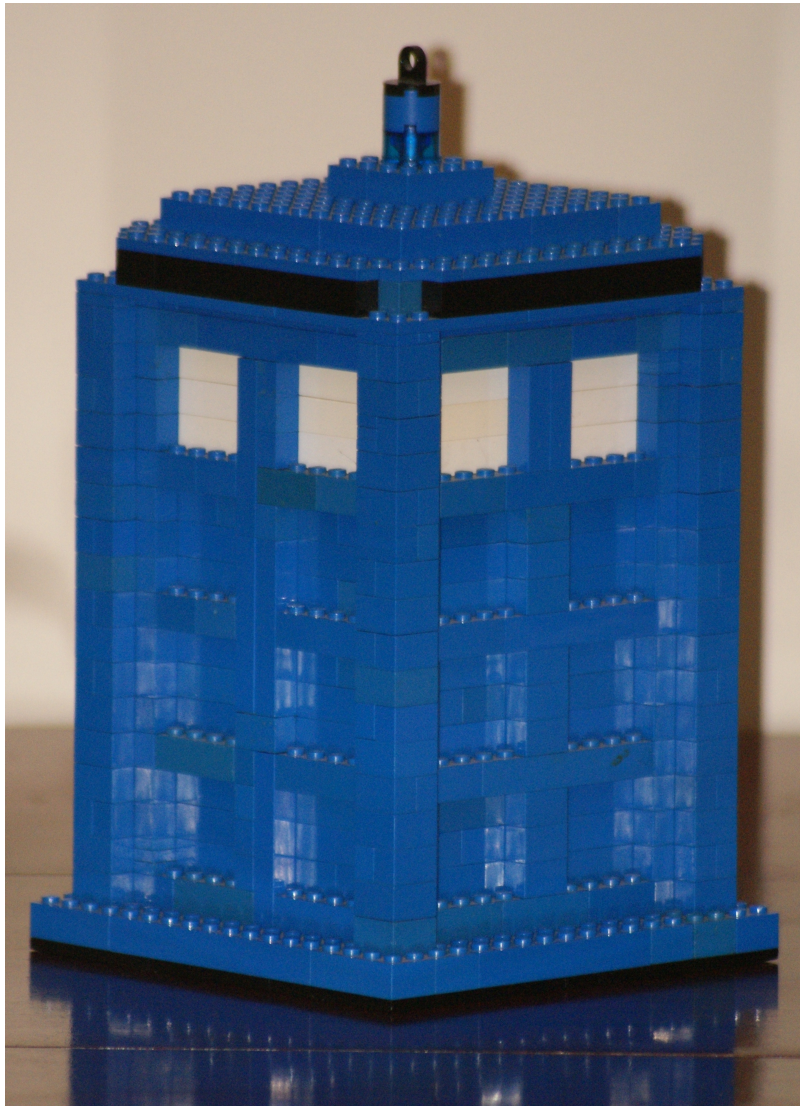
Focal length: 50mm

Distance: ∼60cm



Focal length: 70mm

Distance: $\sim$130cm

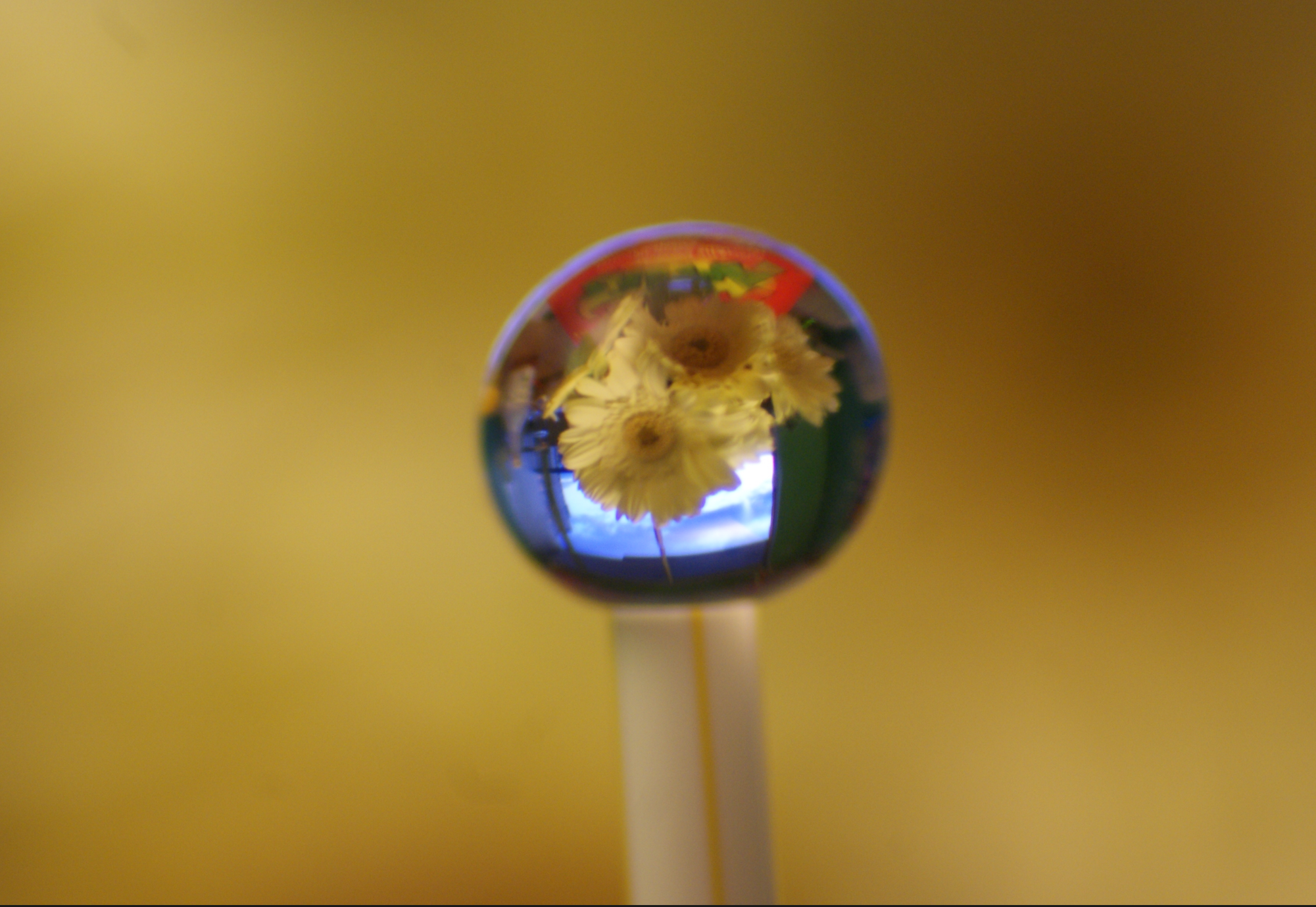


Focal length: 300mm
Distance: ∼450cm

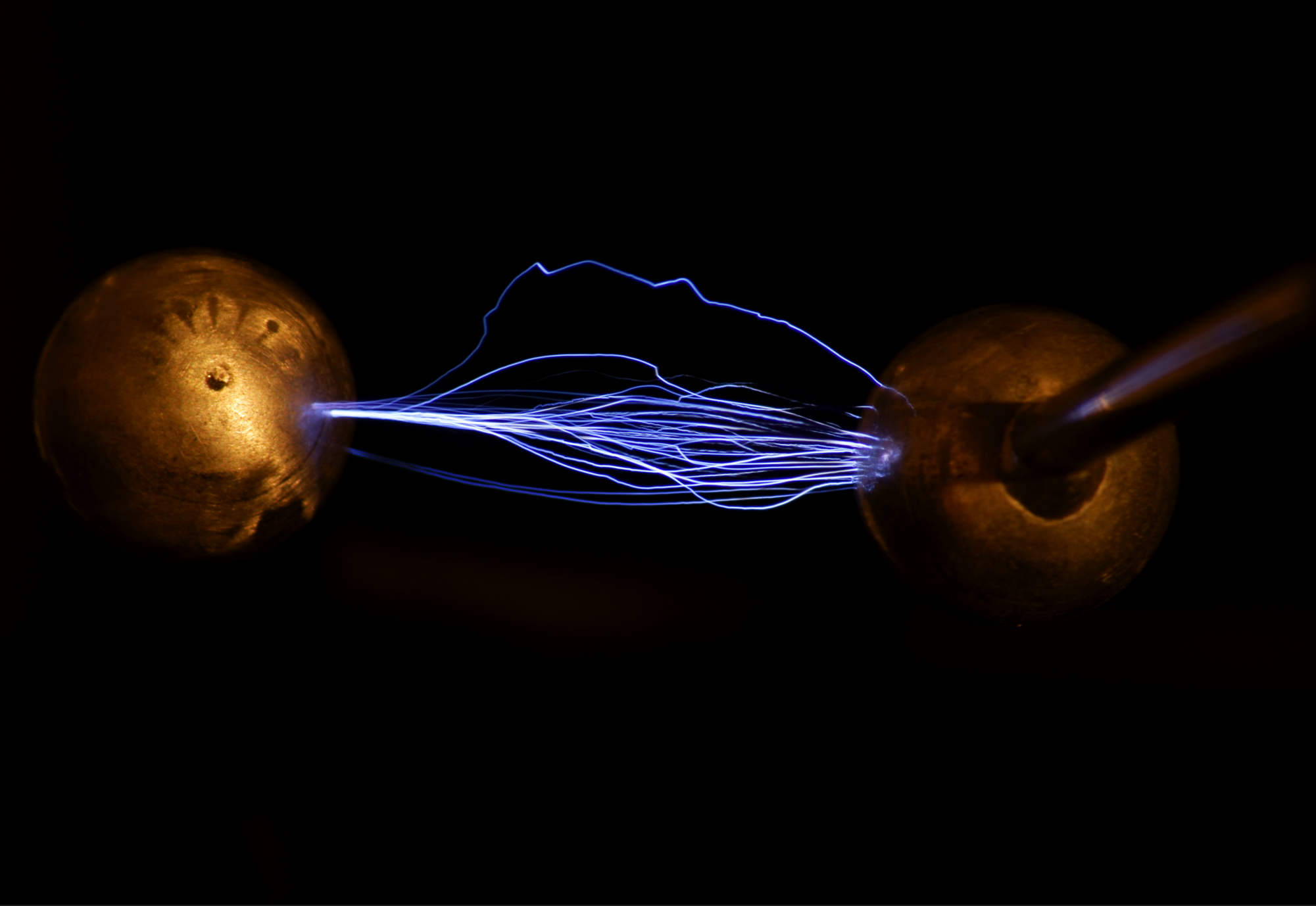
- It's not the focal length that matters here, it's the distance to the object.
- If I had taken a photo of the Tardis from 450cm away using a focal length of 18mm, the Tardis would look the same as the last photo, only smaller (less zoom)
- The distortion comes from seeing an object from a distant perspective, but up close.
- You may be familiar with this effect from movies (particularly the horror genre) when a scene seems to 'telescope' inwards.

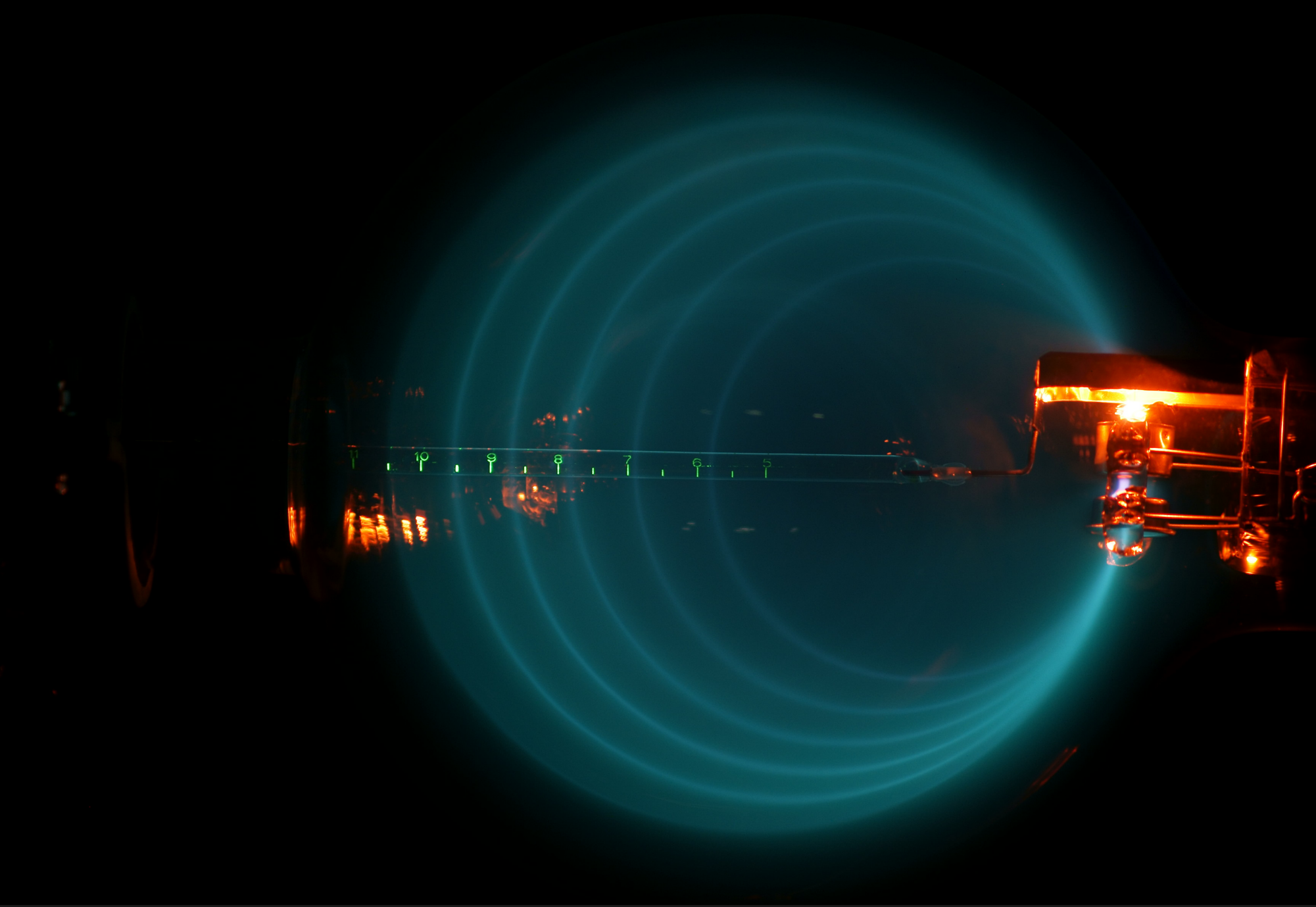
Photographs

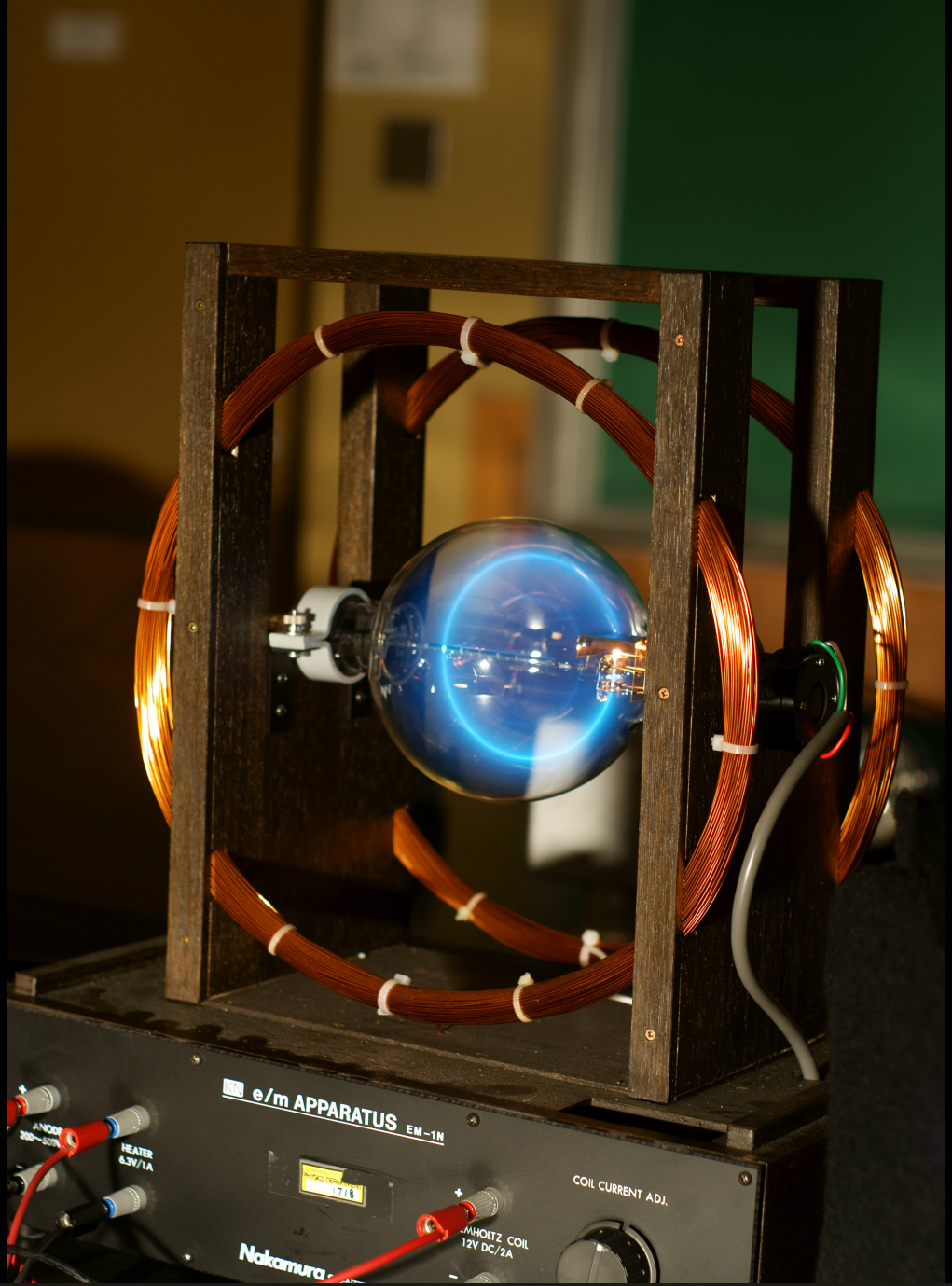
- Here are a few photos that I've taken.




AP. 50 TONS




10
9
8
7
6
5


e/m APPARATUS EM-1N
HEATER
6.3V/1A
COIL CURRENT ADJ.
Nakamura

Conclusion

- There are two ways to control the amount of light reaching the sensor: shutter speed and f-number.
  - Both have side effects: motion blur and depth of field.
  - Either can be used to artistic effect.
- A simple zoom lens consists of a diverging lens which slides between two converging lenses.
  - In practice, zoom lenses are significantly more complex.
- When using higher focal lengths, one should be aware of perspective distortion.
  - Can also be used to artistic effect.
- What is detrimental in one situation may be be desirable in others. The ‘rules’ of photography are really more like guidelines

Sources

- f-stop: http://www.uscoles.com/fstop.htm
- Depth of field: http://www.cambridgeincolour.com/tutorials/depth-of-field.htm
- Zoom lenses: http://www.trustedreviews.com/opinions/how-it-works-zoom-lenses
- Perspective Distortion: http://www.pentaxforums.com/reviews/photo-guide-perspective-distortion/introduction.html
- Wikipedia pages for: Photography, Shutter speed, depth of field.
- My Flickr page: http://www.flickr.com/photos/samdejong/