Cameras

Turn off all electronic devices

Observations about Cameras

They record a scene on an image sensor

Most cameras need focusing, disposable cameras often don't

Camera lenses come in many lengths and widths

Many cameras have zoom lenses

Lenses have specifications such as focal length and f-number

5 Questions about Cameras

1. Why does a camera need a lens?
2. Why do most camera lenses need focusing?
3. Why are lenses telephoto or wide-angle?
4. Why do fancy lens's have internal apertures?
5. Why is a good camera lens so complex inside?

Question 1

Q: Why does a camera need a lens?

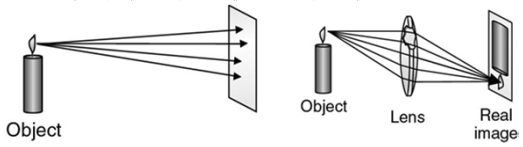
A: Lens bends rays from one point to one point.

An illuminated object reflects or scatters light

- The object's light produces diffuse illumination

A converging lens bends light rays via refraction

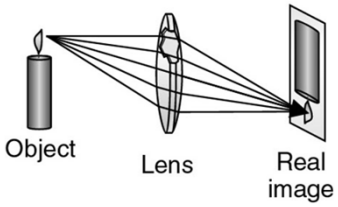
- Light rays spreading from a point converge to a point



Real Images

An image forms in space on far side of the lens

- The image is a pattern of light in space that exactly resembles the object, except for size and orientation
- The image is "real" – you can put your hand in it



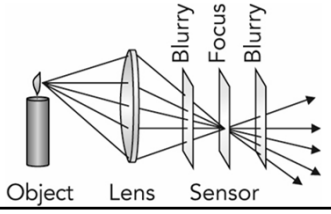
Question 2

Q: Why do most camera lenses need focusing?

A: So that the real image forms on the image sensor.

The sensor records the pattern of light it receives

When focused, the real image forms on the sensor



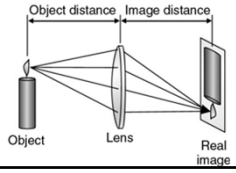
Focusing

Distant object's light diverges slowly
- Real image forms near to the lens

Nearby object's light diverges quickly
- Real image forms far from the lens

A lens focuses light coming from one object distance at a time

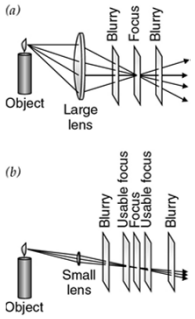
If the object distance changes, the image distance also changes



Lens Diameter and Focusing

Larger lens gathers more light
- so the image is brighter
- but focus is more critical
- and there is less depth of focus.

Smaller lens gathers less light
- so the image is dimmer
- but focus is less critical
- and there is more depth of focus.



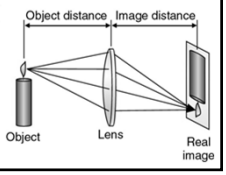
Question 3

Q: Why are lenses telephoto or wide-angle?

A: Lens' focal length (FL) determines image size

Focal length measures lens's converging strength
- Long FL: long image distance, large dim image
- Short FL: short image distance, small bright image

$$\frac{1}{\text{Object distance}} + \frac{1}{\text{Image distance}} = \frac{1}{\text{Focal length}}$$



Question 4

Q: Why do fancy lenses have internal apertures?

A: To vary image brightness and depth of focus

f-number is focal length divided by lens diameter
- f-number determines brightness of the image, regardless of focal length
- Small f-number: bright image, small depth of focus
- Large f-number: dim image, large depth of focus

Sophisticated lenses have adjustable f-numbers
- For low light, fast exposure, or small depth of focus: small f-number
- For bright light, long exposure, or large depth of focus: large f-number

Question 5

Q: Why is a good camera lens so complicated inside?

A: To allow zooming and to correct image flaws

Adjustable focal length allows for zooming

Different glasses fix dispersion-based color focus problems

Anti-reflection coatings reduce reflection-based fogging

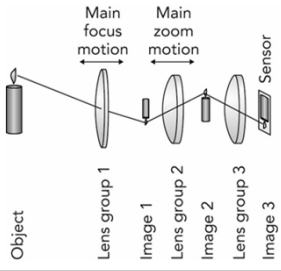
Aspherical lens surfaces fix imperfections due to spherical surfaces

Coma correction fixes poor focusing off the central axis

Astigmatic correction fixes spherical focus on flat image sensor

Zoom Lenses

A zoom lens typically forms three images overall
- Its first lens group produces a real image
- Its second lens group projects a resized image
- Its third lens group projects an image onto the image sensor



Summary about Cameras

They use converging lenses to form real images

Lens focal length sets image size

Lens f-number sets image brightness

The image sensor records the pattern of light