## SAY CHEESE!

If you use a digital camera, getting good photos can seem easy; you point the camera – or maybe your phone – in the right direction and the camera does the rest. But it wasn't always like that. Engineers have spent years developing automatic cameras because, before they existed, most people used to take photos that were blurred or too light (over-exposed) or too dark (under-exposed).

## WHAT YOU HAVE TO DO

You are going to build two simple cameras to find out how non-digital cameras work and why taking good photos is a skilled task. Engineers still need this knowledge because, if they don't know how a manually operated camera works, they cannot build one that works on its own. You are also going to compare different digital cameras and look at things that can affect the quality of the photo you get from a digital camera.

## EQUIPMENT

for the pin-hole camera

- cardboard box with lid (10 - 15 cm long)
- bright, clear, filament lamp
- tracing paper
- thin card
- sticky tape
- scissors
- pins of different thickness
- ruler marked in millimetres
- metre rule
- convex lens
- access to mains electricity

for the lens camera

- bright, clear, filament lamp
- metre rule
- white card screen, with stand
- convex lens, with stand
- ruler marked in millimetres
- access to mains electricity

for the resolution activity

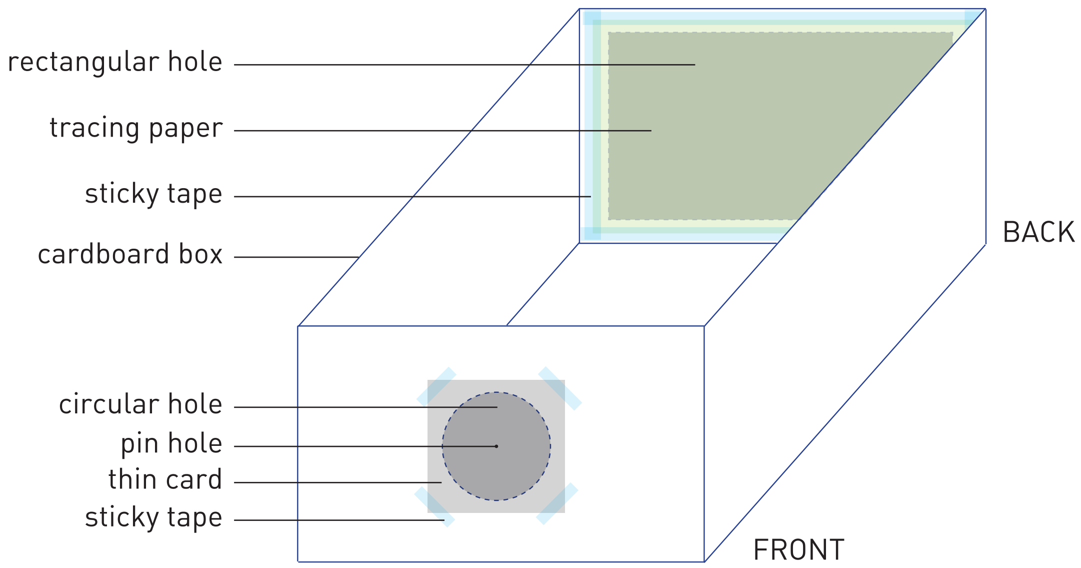
- digital cameras and/or camera phones to give at least three different resolution settings
- access to a means of saving and printing photographs

## SAFETY NOTES

Follow school safety rules when using electrical equipment. Take care when using pins. When they are not in use, place them where they cannot be dropped on the floor. Do not touch bulbs of filament lamps, which may be very hot.

## METHOD: PIN-HOLE CAMERA

1. In one end of the box, cut a rectangle almost as big as the end of the box.
2. Cut a rectangle of tracing paper slightly larger than the hole.
3. Tape the tracing paper to the inside of the box, so it covers the hole. This is the screen.
4. In the centre of the other end of the box, cut a circlular hole. [Note: ask your teacher what size the hole needs to be – you will need to fit a lens in it later.]
5. Cut a rectangle of thin card large enough to cover the circular hole.
6. Make a pin hole (as small as you can) in the centre of the card.
7. Tape the card over the circular hole, on the *outside* of the box. [Note: don't fasten it too securely – you may need to remove/replace it when making different-sized pin holes.]
8. Put the lid on the box. Make sure no light can get in. Cover any gaps with black tape.




9. Hold the pin hole close to a bright filament bulb. Note what you see on the screen.
10. Gradually move it away from the lamp. Note how the image on the screen changes.
11. Make a slightly larger pin hole. Repeat steps 9 and 10.
12. Increase the size of the pin hole and repeat steps 9 and 10 a few more times.
13. Remove the card from the front of the camera and fix a convex lens over the hole.
14. Hold the camera close to the lamp. Move it away, gradually. Observe how the image on the screen changes.

## RESULTS

Describe how the image changed when you:

- moved the camera further away from the filament lamp
- increased the size of the pin hole
- used a lens instead of a pin hole.

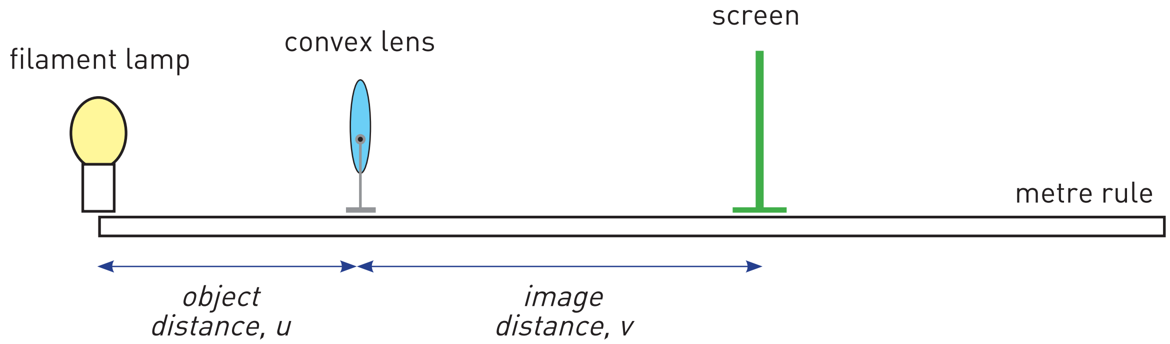
## EXPLANATIONS

1. Explain, using a diagram to help, why the the pin-hole camera image is upside down.
2. What are the advantages and disadvantages of the lens camera compared with the pin-hole camera?

## METHOD: LENS CAMERA

Until the invention of digital cameras, all cameras used photographic film to record the image. The film changed colour when light fell on it. Even very early cameras used a lens instead of a pin hole because the hole just did not let in enough light to record an image on the film.

However, a camera with a lens only gives a clear image when it's at a particular distance from the object being photographed. In this section you are going to investigate how this problem was solved.




1. Place a bright filament lamp (the *object*) so that the centre of the lamp is level with the 0 cm mark on (or just next to) a metre ruler.
2. Your teacher will tell you a minimum distance to use between the centre of the lens and the *object*. Place the convex lens – in its stand – on (or just next to) the metre rule at this distance from the object.
3. Place the card screen - in its stand - along the metre rule, on the other side of the lens from the object. Move the screen backwards and forwards along the metre rule until you see the clearest possible *image* on the screen.

   [If you do not see an image on the screen, it means that the object, lens and screen are not all in a straight line. Use a sheet of white paper to find out where the image is, then adjust the lens and screen until they are in a straight line – you will see an image on the screen. Now adjust the screen until the image is as clear as possible.]
4. Record the *object distance* (the distance between the centre of the lamp and the centre of the lens) and the *image distance* (the distance between the centre of the lens and the screen when the image is clearest). Record your measurements in a table.
5. Increase the *object distance* by 1 cm (move the lens 1 cm further away from the lamp). Move the screen until you again get the clearest possible image. Record *object distance* and *image distance* in the table.
6. Keep repeating Step 5 until you have enough values of *object distance* and *image distance* to plot a graph (at least 6 or 7 pairs of values) or – if possible – until the image distance stays roughly constant.

## RESULTS

| object distance, u / cm | image distance, v / cm |
|---|---|
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1. Use your results to plot a graph of image distance, v (the distance between the lens and the screen) against object distance, u (the distance between the lamp and the lens).
   - The image distance is the dependent variable, so it goes up the *y*-axis.
   - The object distance is the independent variable, so it goes along the *x*-axis.
2. Draw a smooth curve through your points.

## EXPLANATIONS

1. What things may have made your results inaccurate or unreliable? What could you have done to increase their accuracy or reliability?

You probably already know the formula for the magnification of a lens

**magnification = height of image ÷ height of object**

but it can also be found from the formula

**magnification = image distance ÷ object distance**

2. Look at the graph you have drawn. How is the magnification of the lens related to your graph?
3. Use your graph to explain how the magnification changes as the object distance increases.
4. Magnification = 1 (image is same size as object) when the object distance is twice the **focal length** of the lens.
   - What can you say about object distance and image distance when the magnification = 1?
   - How can you find the place on your graph where the magnification = 1?
   - Find this place and use it to calculate the focal length of the lens you used.

## METHOD: RESOLUTION

Advertisements for digital cameras tell you the resolution of the camera in pixels or megapixels (1 megapixel = 1 000 000 pixels). The larger the number of pixels, the higher the resolution. This is useful information – it tells you what quality pictures you can expect. You are going to find out how.

1. Choose an object to photograph. It needs to be very easy to photograph **exactly** the same object again.
   - For example, you might choose to photograph a scene outside a window, making sure that the edges of the window frame are at the edges of your photograph.
   - Choose a snapshot picture that all cameras can photograph, rather than a close-up that may need a special setting.
2. Take at least three photographs of the same object using either:
   - the same camera set to a different resolution for each photograph, or
   - a different camera or camera phone, with a different resolution, for each photograph.

   [If you use different cameras, you may need to change position slightly to keep the photograph the same, as the lenses may be slightly different.]
3. Print out each of your photographs, making sure that they are all the same size. Label each picture with the resolution used to take the photograph.
4. Choose one photograph, from the middle of the range of resolutions you used, and print out copies in several different sizes, from A4 down to postage stamp size.

## RESULTS

1. Compare the pictures you printed out in Step 3. Describe how the picture changes when the resolution changes.
2. Compare the pictures you printed out in Step 4. Describe the effect of changing the size of the print.

## EXPLANATIONS

1. Read again the description of what *resolution* and *number of pixels* means. Explain why you got the difference you did for different resolution cameras.
2. Imagine a friend or relative is happy with a photo they took on holiday, but were unhappy with the result when they printed an enlarged copy. Explain to them what the problem is.

## SOME THINGS TO THINK ABOUT

- For your lens camera, the magnification got smaller as the distance between the lamp (the object being *photographed*) and the lens increased. Relate this to the size of the object and the image when you use a real camera. Is it what you would expect?
- A friend is going to buy a digital camera. What would you tell them to think about, to make sure they buy a suitable camera for the pictures they want to take?
- Talk to some people who have used a film camera. What do they think are the advantages or disadvantages of digital compared with film cameras?

## HEALTH AND SAFETY

A risk assessment must be made before starting any practical work.

Students should follow school safety rules when using electrical equipment. Make sure they take care when using pins and do not touch bulbs of filament lamps, which may be very hot.

## THE INVESTIGATION

Most students today will be unfamiliar with how a camera works – the workings of digital cameras or camera phones are not immediately obvious. However, at its most basic level, the features of a digital camera are the same as a 'film camera' – there is a lens or a series of moveable lenses that focus light from an image onto a light recording device. It is this element of cameras that students are going to investigate. They can then look at the effect that resolution has on the photo they see.

The investigation is in three parts. In the first part, students make a simple pin-hole camera and look at the effect of changing the size of the hole and changing the distance of the camera from the object being 'photographed'. In the second part, students use a lens to form an image on a screen and investigate how to form a clear image when the distance between the object being 'photographed' and the lens, changes. In the final part, students use digital cameras and/or camera phones to investigate the effect of changing the resolution and of changing the physical size of the picture printed.

## RESULTS

### The pin-hole camera

Students should find that a pin-hole camera with a small hole produces a clear, but dim, image whatever the distance of the camera from the object. Increasing the distance between the camera and the object will make the image smaller. Increasing the size of the pin-hole will make the image brighter, but will also make it less clear. This is a good starting point for discussion about why people started to build lens cameras, when a pin-hole camera always produced clear images.

You may also wish students to be aware of other connected points for discussion, such as what a 'camera obscura' is, or the fact that primary school teachers often spot children who are needing spectacles for the first time because these children partially close their eyes to make their vision clearer (by decreasing the size of the hole through which light enters their eye they are, in effect, turning their eye into a pin-hole camera, with a clearer image).

In their comparison between a pin-hole camera and a basic lens camera, the most obvious advantage students will notice is that the image formed by a lens camera is much brighter, so it can take pictures in a wider range of lighting conditions. The most obvious disadvantage is that the image is only in focus when the camera is at one particular distance from the object being photographed – a very major disadvantage!

### The lens camera

Lens cameras were invented to allow enough light into a camera to change the film to produce a photograph in a reasonable length of time – even so, exposure times with early cameras had to be long, making photography of moving objects difficult. Students have already found out that the problem with replacing a pin hole with a lens is that they only get a clear image with the camera in one position.

Here they investigate how changing the distance between the lens and the back of a camera (represented here by a white screen) enables a clear image to be formed for a range of distances between object and lens. Provided that the distance between the object and the lens is more than the focal length of the lens (you will need to tell students what minimum distance to use here – details of how to find the focal length for a convex lens are given below), they will find that the image formed on the screen:

- is inverted (upside down)
- decreases in size as the distance between lens and object increases, and
- is formed closer to the lens as the distance between object and lens increases.

Plotting a graph of image distance against object distance will give a curve, with the gradient decreasing as the object distance increases, showing that the magnification of the lens decreases as the object gets farther away.

### Finding the focal length of a lens

Your lenses may already be labelled with their focal length. If not, you can find the focal length using a ray-box and slits. Arrange the slits in front of the ray-box so that the ray-box gives three parallel rays of light. Place the lens across these rays of light so that all three rays pass through the lens and the centre ray passes through the centre of the lens. The rays will cross over on the opposite side of the lens to the ray-box. The distance between the centre of the lens and the point where the rays cross is the focal length of the lens. In their lens camera investigation, students must use object distances (the distance between the object – usually the filament lamp - and the lens) that are greater than this focal length.

### Resolution

The resolution of a digital camera gives an indication of the picture quality to expect. The resolution is given in pixels or megapixels (1 megapixel = 1 000 000 pixels). The number of pixels indicates how many dots the picture will be stored and printed as: a 1 megapixel camera records and displays pictures using 1 000 000 coloured dots. Students will find that using a higher resolution gives a better quality (less 'grainy') photo as there are more dots in the stored and printed picture, so a finer amount of detail is possible. Students will also find that a photo taken using a set resolution looks increasingly 'grainy' as the size of the printed picture is increased, because the number of dots remains the same but each individual dot gets larger.

## SUGGESTED SEQUENCE

All three of these activities could be carried out by students working in pairs. If using groups of three or more, you may need to ensure students distribute tasks reasonably so no-one is not left with nothing to do while measurements are being taken and recorded. There is no necessity for students to work in the same groups for the practical activities and for the 'Results' or 'Explanation' work, so you may wish 'practical' groups to combine to share findings and ideas. For graph plotting, you may wish to put weaker students in groups where others can support them in drawing and evaluating their graphs.

### Time required

Each of the practical investigations will be completed by students in one practical session, though you may wish to allow further time for plotting graphs and evaluating results.

### Notes

**Building a pin-hole camera:** A pin-hole camera can be made from any light-proof box with a small hole in one side and a translucent screen on the opposite face. Students can readily build one using a small cardboard box. (It doesn't have to be a cuboid – cardboard cylinders are also suitable.)

The distance between the front and back faces of the pin-hole camera is not critical, but about 10 to 15 cm works well.

The simplest arrangement for the pin-hole is to cut a hole in the centre of the front of the box large enough to take a lens for the lens camera activity and then cover this with a sheet of opaque paper or thin card. Pin-holes of varying sizes can then be made in the centre of this paper or card. The opposite (back) face of the box should have a large hole cut (or removed completely) and covered with tracing paper or a similar translucent material, so that the image formed on the back of the camera is visible.

Students may have difficulties keeping the pin-hole camera pointing directly at the filament lamp, in which case they may have difficulty getting the image to form on the screen rather than off to one side of the screen. This problem can be overcome by sliding the camera along a metre ruler with one end at the lamp. This also enables them to measure easily the distance between the lamp and either the front or back of the camera.

**The lens camera:** This activity requires students to change the distances between object and lens and between object and screen. Since this is difficult to do if the lens and screen are confined within a camera, students simply use a lens in a stand and a screen to represent the back of the camera. Measurements of distance are much easier to make if the lens and screen are in holders that can be either attached to a metre rule or placed next to it. Students should measure distances to the central plane of the lens (that is half way between the curved faces) and to the centre of the filament lamp.

Some students may need reminding how to find the gradient of a curve by drawing a tangent to the curve. Be prepared to provide extra help to do this if students need it.

In the method suggested, students focus the image of a bright filament lamp on a screen. If you do not have bright, clear filament lamps, students could use an object such as a pin in a cork, or cross wires, lit from behind, and focus a clear image of this on the screen instead. The disadvantage of this method is that it is harder to find the exact position of the clearest image, since the image will appear reasonably clear over a fairly wide range of positions.

Both the pin-hole camera activity and the lens camera activity can be carried out without needing to dim the lighting, but if the lighting can be dimmed slightly, students will find images easier to see.

## TECHNICIAN EQUIPMENT LIST

per group

for the pin-hole camera

- small cardboard box or cardboard cylinder, 10 – 15 cm long
- bright, clear, filament lamp in a PAT tested folder
- tracing paper
- opaque paper or thin card
- sticky tape
- scissors
- pins of different thicknesses
- ruler marked in millimetres
- metre ruler
- convex lens
- access to mains electricity

for the lens camera

- bright, clear, filament lamp
- metre ruler
- white card screen, with stand
- convex lens, with stand
- ruler marked in millimetres
- access to mains electricity

for the resolution activity

- digital cameras and/or camera phones to give at least three different resolution settings
- access to an electronic means of saving and printing photographs