**Getting focused**

This demonstration explains step-by-step how many light rays from each point of an object are refracted by a lens so they all cross over at a corresponding point on the other side of the lens. Repeating the demonstration for light rays from another point of the object shows how a sharp image is formed on a single focal plane.

**Safety**

Some demonstration ray boxes use laser light.

**Apparatus and materials**

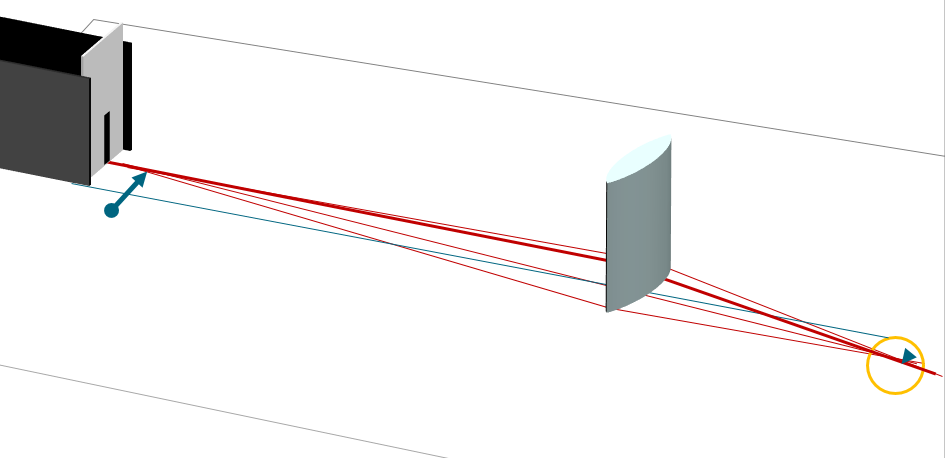
* Power supply
* Ray box
* Collimating lens
* Single slit
* A2 sheet of paper (or two A3 sheets stuck together)
* Cylindrical converging lens (focal length of approximately 10 cm)
* 50 cm ruler

**Procedure**

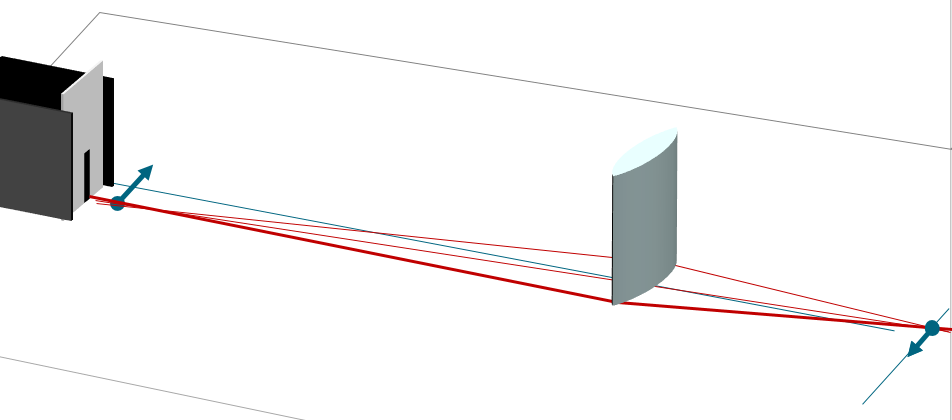
30 cm

* **Set up**
* On a sheet of A2 paper rule a line along the centre.
* Towards one edge draw an object, with a height that is less than the width of the lens being used.
* Draw a line for the lens about 30 cm in front of the object.

**2. Plotting rays from the top of the object**

* Use a ray box with a single slit to plot three or four different rays of light through the lens.
* Use the whole width of the lens.
* Each ray should pass through the tip of the object that has been drawn.
* Each ray should cross at one point behind the lens.
* Slight movement of the lens can easily make plots miss the cross over point and small adjustments may be necessary to ensure a convincing demonstration.

**3. Plotting rays from another point of the object**

* Step 2 is repeated from a different point on the object. The most obvious point is the bottom of the object.
* Each ray should pass through the same point of the object and cross at one point behind the lens.
* The rays should cross the same distance behind the lens as the first set of rays. This is the focal plane.
* Each point of the object can be plotted in this way, and all the rays passing through the lens will cross to distinct points that are all the same distance behind the lens. The points are distributed across the focal plane to form an inverted image of the object.

**Possible questions to ask during the demonstration**

* What does the lens do to the light ray? (Refract it towards the centre line)
* How are light rays hitting the edge of the lens refracted differently than those hitting the centre of the lens? (Refracted at larger angles)
* How many light rays come from each point of the object? (Many – an infinite number because light moves in all directions from each point)
* Do all the rays from a point of the object pass through the lens? (no – most miss the lens)
* How many of the light rays from a point of the object are refracted to a single point on the opposite side of the lens? (All of those passing through the lens)
* What is special about the lens that makes all the light rays from a point of the object cross at a single point behind the lens? (Its shape – which has to be very precise)
* Would some of the rays from a point of the object still reach the single point if some of the lens was blocked? (yes – but fewer rays would reach the point so it would not be so bright)
* What do you think will happen to light rays from a different part of the object? (They will all cross at a single point too; the point will be the same distance behind the lens, because the lens bends light by the same amount each time; where they cross is shifted sideways from the first crossing point, because they start from a different position.)
* What do you think you will see if you plot light from every point of the object? (An inverted image of the object)

*Physics > Big idea PSL: Sound, light and waves > Topic PSL3: Making images > Key concept PSL3.2: Refraction and lenses*

|  |
| --- |
| **Response activity** |
| **Getting focused** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | All light from each point of an object that passes through a converging lens is bent (refracted) to a corresponding point in a sharp image. |
| Observable learning outcome: | Explain how the shape of a lens enables it to focus light.  Explain how light from an object can be focused by a converging lens to form a sharp image. |
| Activity type: | Clarifying - demonstration |
| Key words: | Refract, lens, focus, image |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

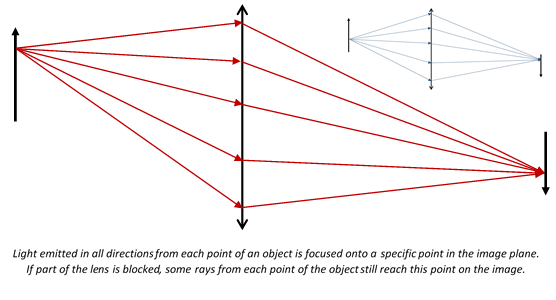
* Diagnostic question: Light bends
* Diagnostic question: Through a lens

**What does the research say?**

Bryan and Slough (2009) found it common for students aged 12-15 (n=73) to draw single parallel rays of light from each point of an object in order to explain a prediction that covering half of a lens results in half the image disappearing. Part of the reason students form this misunderstanding may be due to their being shown how a lens refracts three parallel rays of light from a ray box.

The misunderstanding that covering half of a lens results in half the image disappearing is held by the majority of students of all ages (Goldberg and McDermott, 1987; Galili and Hazan, 2000; Ceuppens et al., 2018; Favale and Bondane, 2013).

Bryan and Slough (2009) tested a range of computer simulations designed to improve understanding of image formation with students, in order to identify features that improved learning. They found that the number of rays included from each point did not have an effect on student predictions about image formation when part of a lens is covered. By contrast simulations in which rays were shown originating from different parts of the object had a positive effect on student understanding.

The diagram shown here illustrates rays of light form two points on an object being focused by a converging lens to corresponding points on the image. If part of the lens is blocked off then it can be seen that some rays of light from each point of the object will still be able to be focused by the lens to form part of a complete image.

**Ways to use this activity**

This demonstration gives you the opportunity to teach a challenging concept, and show your students how it builds up from simpler ideas, using a structured teacher-led discussion.

You should use carefully selected questions to check your students’ understanding of each step, before progressing onto the next one.

Full details of the demonstration and suggested questions are provided in the *demonstration notes*.

With some classes it may be appropriate to consolidate understanding by allowing students to carry out the practical work independently.

*Differentiation*

You could challenge different individuals by asking them follow-up questions to clarify or to extend their original answer. If a student is having difficulty with a particular question, it is often helpful to break it into smaller *chunks*, to lead them to a fuller answer. This technique models more thorough answers, and can be used to support an open classroom culture in which students are encouraged to ‘have a go’.

**Equipment**

For the demonstration:

* Power supply
* Ray box, Collimating lens, Single slit
* A2 sheet of paper (or two A3 sheets stuck together)
* Cylindrical converging lens (focal length of approximately 10 cm)
* 50 cm ruler

**Technician notes**

The idea cylindrical converging lens will be wide, stable and not easily topple over.

Ray boxes which use lasers are now available for demonstrations. Some of these are magnetic and can be used on a steel white board.

**Health and safety**

If a laser ray box is used then appropriate health and safety procedures must be followed.

If students carry out their own practical work: ray lamps get very hot; and if power packs use mains, then they need to be checked for damaged plugs and loose wires.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

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Ceuppens, S., et al. (2018). Tackling misconceptions in geometric optics. *Physics Education,* 53**,** 10.

Favale, F. and Bondane, M. (2013). Misconceptions about optics: an effect of misleading explanations? *Education and Training in Optics and Photonics.* Porto, Portugal: OSA Publishing.

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Goldberg, F. M. and McDermott, L. C. (1987). An investigation of student understanding of the real image formed by a converging lens or concave mirror. *American Journal of Physics,* 55**,** 108-19.