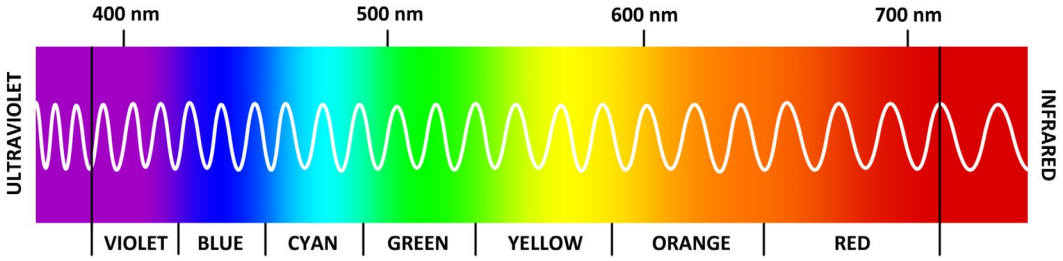
Light Notes

Science Exams Sorted www.scienceexamssorted.co.uk

Light: or visible light, is a form of electromagnetic radiation that can be seen by the eye.

Visible light is made up of a number of different wavelengths of light. The figure below shows the visible part of the electromagnetic spectrum.



We can see from this figure that each colour of light has its own wavelength. In a vacuum, all colours of light travel at exactly the same speed (the speed of light). However, when light enters a medium like glass or water, its speed changes.

Different colours slow down by slightly different amounts. Violet light slows down the most and red light slows down the least. This difference in speed inside a medium is what causes white light to split into a spectrum (dispersion).

Note: this is how we can separate light into its different colours 😊 as each travels at different speeds they refract at different angles. We cover refraction later in this booklet.

A luminous object: an object that emits its own light for example the sun or a light bulb.

A non-luminous object: an object that reflects light that has been given out by another source for example the moon or a desk or a door. Most objects are non-luminous objects.

Key Light Facts

Light travels in straight lines.

The speed of light is 300 000 000 m/s.

Light can be reflected.

Light can be refracted.

Light can be absorbed by a material.

White light is made of three primary colours.

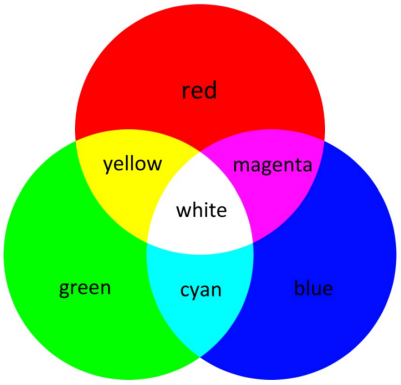
The Colours of Light

White light is made up of **three primary colours**. These are **red**, **green** and **blue**. Yellow is not a primary colour in physics. Yellow is a primary colour in art but not in physics.

Exam note: do watch out for this. There have been more than a few multiple choice questions on the primary colours of light where they have given yellow as an option. They are trying to catch you out here.

What are primary colours? Primary colours are wavelengths of light that can be combined to create secondary colours.

Secondary colours: are colours that are made from mixing primary colours. The secondary colours in physics are magenta, cyan and yellow. Please see the figure below which shows the primary and secondary colours of light.



Red light + blue light = magenta

Red light + green light = yellow

Green light + blue light = cyan

Colour filters and Absorption

When we're talking about light and we mention filters we probably think of different filters that we can use on our smart phones. While that's different than standard colour filters the idea is the same, they let some colours in but not all.

Colour filters: are materials that allow certain wavelengths of light to pass through, and absorb others.

Before we go on, something we should point out is that **colour doesn't actually exist**. That sounds strange! Yes. But, it's true. Let's take red letter boxes for example, white light shines onto the red letter box. Why does it look red then?

The red letter box looks red as the red wavelengths of the light spectrum are reflected from the red letter box. That light enters our eye and our brain understands that that wavelength of light means red. So, it looks red to us.
But what happened to the blue and green wavelengths of light? They **were absorbed** by the letter box. So, they were **not reflected**.

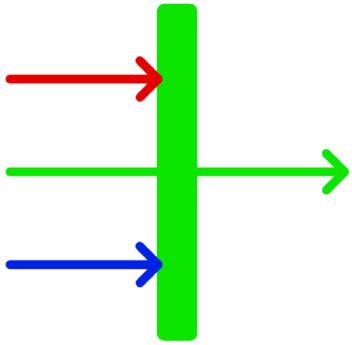
The wavelengths of light that are reflected and absorbed determine what colour something looks like to us. It's just wavelengths of light. Colour isn't real.

Blue cars aren't blue, they just reflect the blue light and absorb the red and green light.

Where do we use colour filters?
Some really good examples of colour filters are **traffic lights, or brake lights** on cars or any vehicle really.

How do colour filters work?
Let's explain this using the examples we talked about above.

Traffic lights – The bulb inside a traffic light typically produces white light. A coloured glass or plastic filter is then placed in front of the bulb. This filter absorbs certain wavelengths (colours) and only allows others to pass through.



Traffic light – green filter

The figure to the left shows a green traffic light filter.

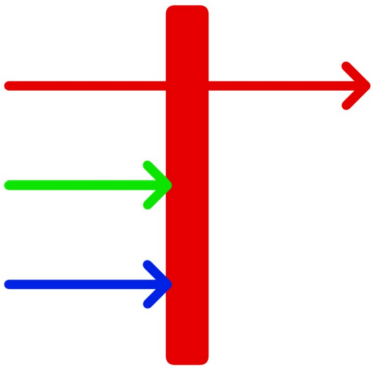
As we can see, the three primary colours (white light) are given out by the light source.

The red light and blue light are absorbed by the filter and the green light passes through. So the light appears to be green in colour.

The figure to the right shows a red brake light filter.

As we can see, the three primary colours (white light) are give out by the light source.

The green light and blue light are absorbed by the filter and the red light passes through. So the light appears to be red in colour.



Brake light – red filter

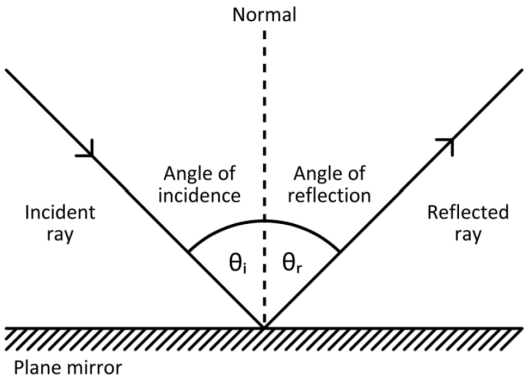
What if we shine blue light onto a white dress? As the dress is white it would reflect the blue light so the dress will appear blue.

What if we shine a red light onto a blue shirt? The blue shirt will absorb the red light so the shirt will appear to be black.

Law of Reflection

The law of reflection: states that <u>the angle of incidence is equal to the angle of reflection</u>. $\theta i = \theta r$.

That symbol is a theta (θ) in terms of light we use theta to mean "angle of" so θi means angle of incidence.



The incident ray: the ray of light that comes **in** to the system. The angle of incidence is the angle between the incident ray and the normal.

The reflected ray: the ray that comes out of the system. The angle of reflection is the angle between the reflected ray and the normal.

Specular reflection: reflection from a smooth surface (like a mirror) in a single direction.
Diffuse reflection: reflection from a rough surface (like paper) that scatters the light in all directions.

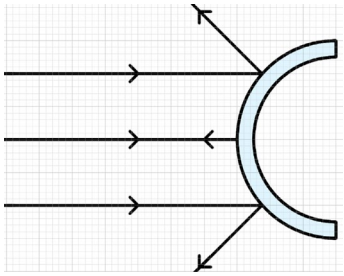
Where is reflection used: in anything that has a mirror 😊 Let's look at mirrors 😊 no pun intended.

Mirrors

There are different kinds of mirrors that light can be reflected by these are plane, convex and concave.

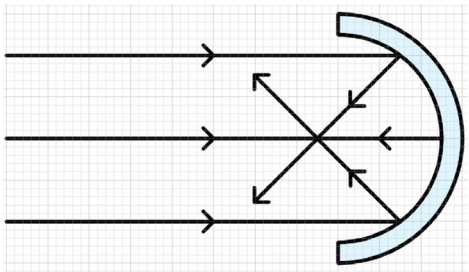
A plane mirror: a flat reflective surface that produces images through the reflection of light. For example, a standard mirror or flat surface of a lake.

Convex mirror



Convex mirrors disperse light.

Concave mirror



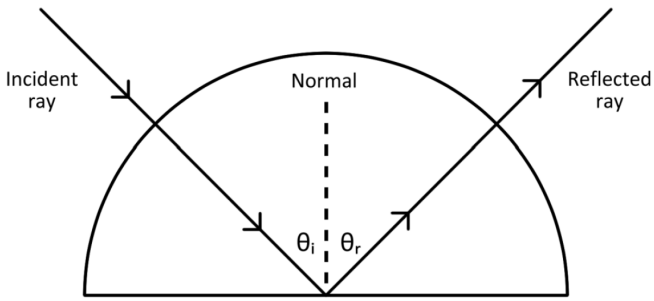
Concave mirrors converge light.

Total Internal Reflection (TIR)

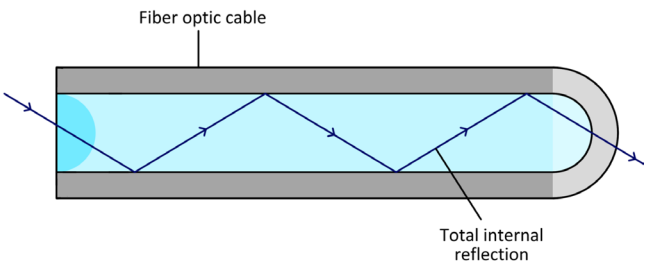
Total internal reflection: is when a wave (in this case light) is totally reflected from the internal surface of a material.

When does total internal reflection occur? When the angle of incidence is <u>greater</u> than the critical angle of the material. **The critical angle**: is the angle of incidence that causes the angle of refraction to be exactly 90 degrees.

Where is total internal reflection used: fibre optic cables.



Total internal reflection inside a glass prism



Total internal reflection inside a fibre optic cable

Refraction

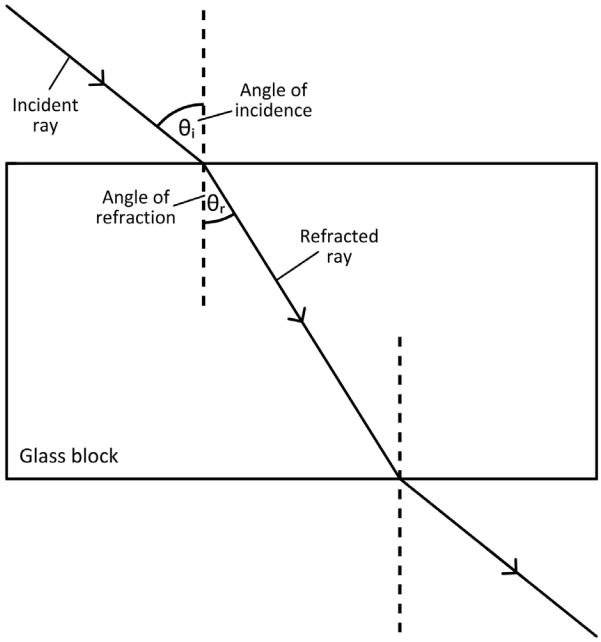
Unlike reflection, there isn't one simple rule for the angles. Instead, the angle depends on whether the light wave is speeding up or slowing down as it crosses the boundary! Here are the two rules we must know:

1. **Light entering a more dense material** (e.g. air into glass): **The light slows down**. This causes it to bend towards the normal. In this case, the angle of incidence is greater than the angle of refraction ($\theta i > \theta r$).
2. **Light entering a less dense material** (e.g. glass into air): **The light speeds up**. This causes it to bend away from the normal. In this case, the angle of refraction is greater than the angle of incidence ($\theta r > \theta i$).

Note: If light hits a boundary head-on (exactly along the normal line), it will change speed but it will not change direction!

Exam hint: A handy way to remember which way the light bends is the word **FAST**:

Faster → **A**way from the normal **S**lower → **T**owards the normal 😊



Refraction: is the change in direction and speed of a wave as it enters or leaves a material with a different refractive index.

Refractive index: of a material is a measure of how much light is refracted as it passes through it. Refractive index is really a measure of optical density. The greater the optical density of an object is the more light is refracted as it moves through it.

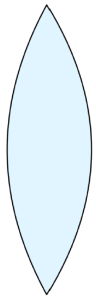
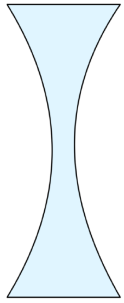
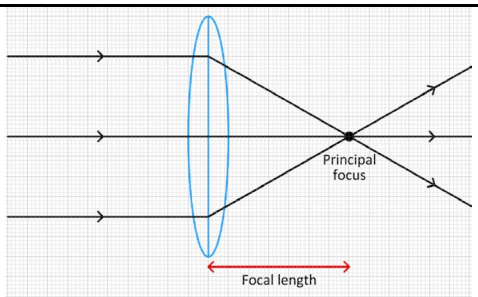
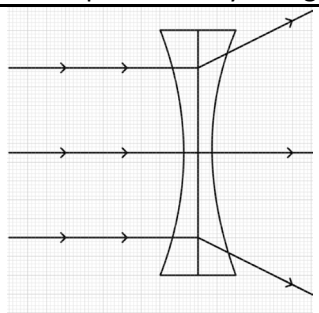
The figure shows refraction in a glass block

Lenses

There are a number of different types of lenses, for the GCSE, we study two types of lenses, **convex** and **concave** lenses. Before we look at the lenses let's look at a few key terms which get used quite a lot when talking about lenses.

Focal point also known as the **principal focus**: It's the point where the lens focuses light.

Focal length: is the distance from the centre of the lens to the focal point/principal focus.

Convex lenses	Concave lenses
Convex lenses: are thicker in the middle than at the ends. Convex lenses have a positive (+) power.  **Convex lens** **Symbol for a convex lens** **Note:** they are also known as converging lenses because they focus light onto one point.	**Concave lenses:** are narrow in the middle and thicker at the ends. Concave lenses have a negative (−) power.  **Concave lens** **Symbol for a concave lens** **Note:** they are also known as diverging lenses because they spread out or disperse the rays of light.
 **The figure above shows a convex lens focusing light.**	 **The image above shows a concave lens dispersing light.**
Convex lenses form real images.	Concave lenses form virtual images.

A real image: is an image formed when light rays converge, real images can be projected onto a screen or surface.

A virtual image: is an image that forms when light rays appear to diverge from a certain point, a virtual image cannot be projected onto a screen.

Calculating the magnification of a lens

Magnification is the term given for how much bigger an image is than the original object. Magnification doesn't have a unit but we normally put an x in front to show that something has been magnified for example **x50** would be magnified by 50 times its original size.

How can we calculate the magnification of a lens?

$$\textbf{Magnification} = \frac{\boldsymbol{image\ height}}{\boldsymbol{actual\ size}}$$

Let's look at an example: an object has an actual size of 4 cm and the image produced by a convex lens is 8cm. Calculate the magnification of the lens. Here we will just use the equation above with some substitution.

$$\text{Magnification} = \frac{image\ height}{actual\ size} \qquad \text{Magnification} = \frac{8}{4} \qquad \text{Magnification} = \text{x2}$$

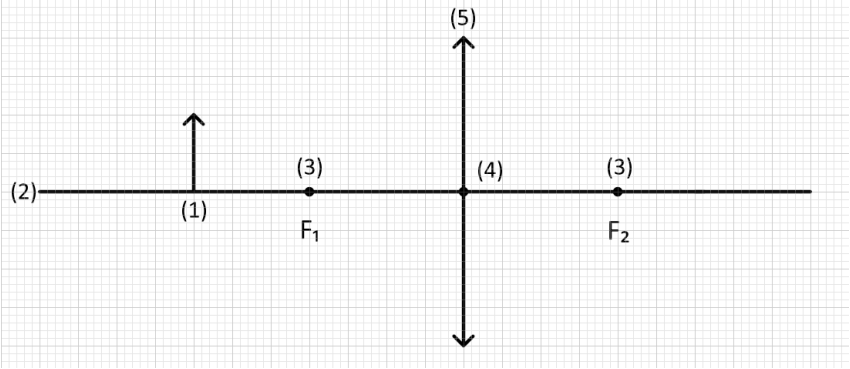
The image is **twice** the size of the actual object.

Lens Ray Diagrams

What are lens ray diagrams? A lens ray diagram is visual guide that shows us how light travels through a lens. For the GCSE we need to be able to draw ray diagrams for both convex and concave lenses.

What can we be asked about lens ray diagrams? Most questions have a part drawn diagram and then we're asked to complete it. We are also sometimes asked to draw the correct symbol for the lens that the question has asked for. We need to make sure that we have learned the symbols for both convex and concave lenses.

What do lens ray diagrams look like? Check out the example below 😊



The example here shows a lens ray diagram for a **convex** lens that hasn't been completed.

Let's look at the various parts of the ray diagram. We don't need to know about most of these in any great detail but it's still very good to know what they are.

1. **Object**: is the source of the light rays that will form the image. This is typically draw as being the top of an arrow. But the arrow isn't necessarily needed. It could be any point above the principal axis.
2. **Principal axis**: This is the horizontal line (x axis) that passes through the optical centre of the lens.
   It is a reference line that helps us understand where the light rays meet and how the image is formed.
3. **Focal points**: for the GCSE lens ray diagrams we draw two focal points. One in front of the lens which is used more as a point of reference and the second to give us an idea where the light rays will converge in a convex lens ray diagram. There are more focal points but we don't use or draw these at GCSE.
4. **Optical centre**: This is the exact centre of the lens.
   A light ray passing through this point goes straight through the lens <u>without changing direction</u> because it is aligned along the principal axis.
5. **Lens**: this can be either convex or concave depending on what the question has given us or what the question is asking us.

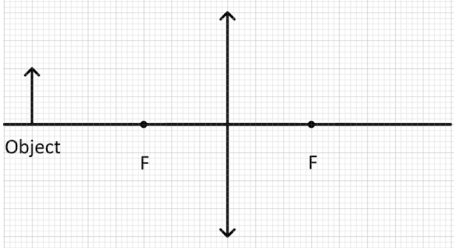
Convex lens ray diagrams

A question could look like the following diagram... Let's use this as an example of how to complete a ray diagram 😊

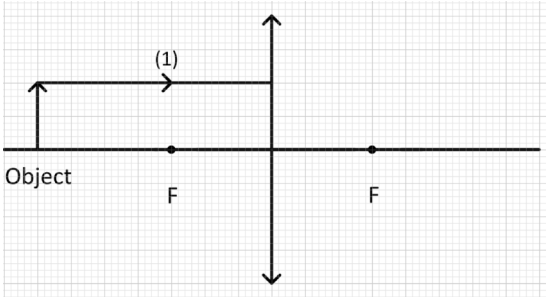
The diagram to the right shows part of a ray diagram for a convex lens. This is very similar to how a question may appear in an exam.

A question may then ask you to complete the ray diagram.

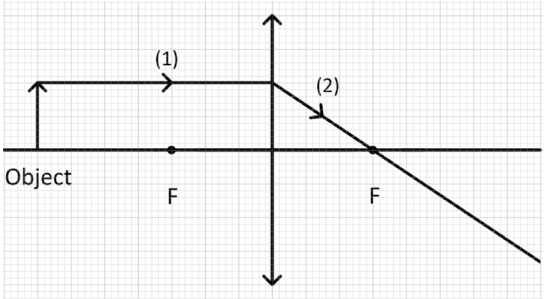
Let's look at the steps below to see how we should do this for a convex lens.



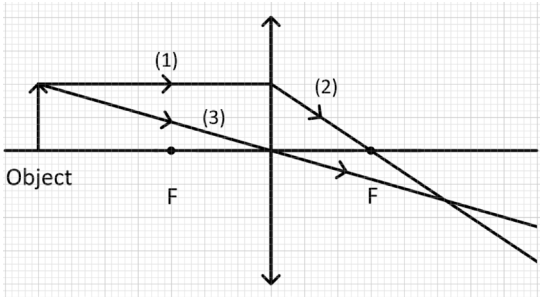
How to draw a ray diagrams for a convex lens step by step…



Step 1: draw a ray from the top of the object, parallel to the principal axis, to the lens.

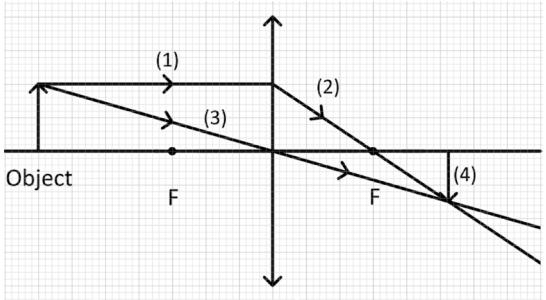


Step 2: from the point where the ray touches the convex lens extend the line down through the second focal point.



Step 3: draw a straight line from the top of the object through centre of the lens (optical centre) and extend it on the other side of the lens.

We notice that this new ray touches the previous ray which has been refracted by the lens.



Step 4: where the two rays meet draw an arrow to meet this point from the principal axis.

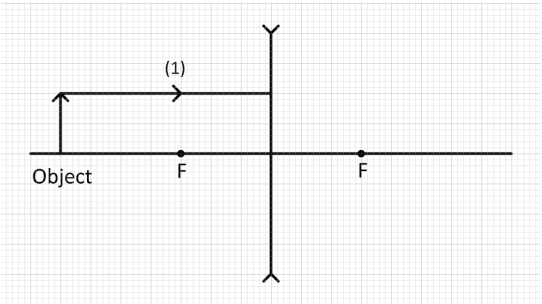
This represents where the image of the object would form.

We could be asked to describe the image that is formed.

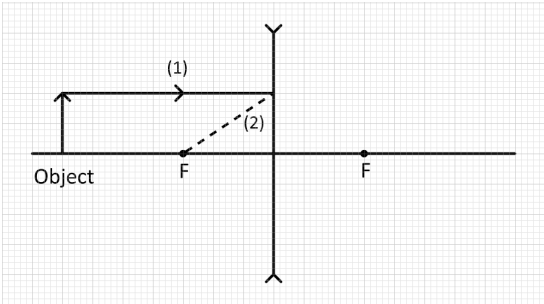
This image is <u>real</u>, it has been <u>inverted</u> and it is <u>diminished</u>.

Concave lens ray diagrams

How to draw a ray diagram for a concave lens step by step…



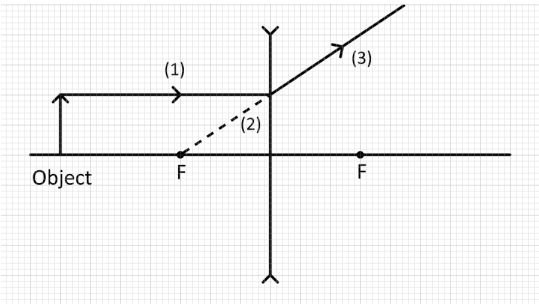
Step 1: draw a ray from the top of the object, parallel to the principal axis, to the lens.



This is where is gets a bit different. Instead of going forwards the next thing we need to do is draw a line going backwards.

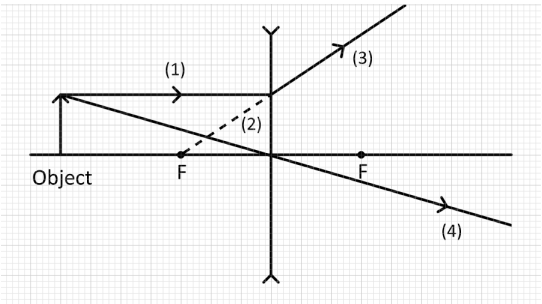
Step 2: At the point where the ray hits the concave lens, draw a dotted line from here back to the first focal point.

The line <u>must be dotted</u> as this is an imaginary line so it doesn't really exist.

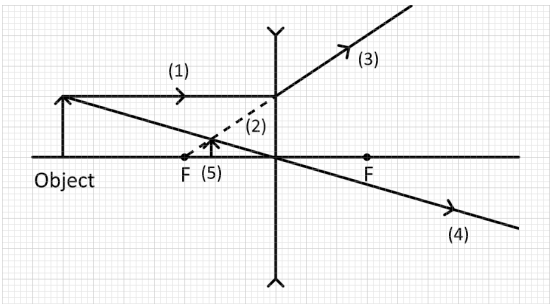


Step 3: continue the imaginary line from step 2 forward through the lens and extend it past the lens. This line should now be a solid line as it represents a real light ray.

This light ray should be drawn at the same angle as the imaginary ray was from step 2.



Step 4: draw a straight line from the top of the object through centre of the lens (optical centre) and extend it on the other side of the lens.



Step 5: where the ray from step 4 meets the imaginary line from step 2, draw an arrow to meet this point from the principal axis.

This represents where the image of the object would appear to have come from.

We could be asked to describe the image that is formed.

This image is <u>virtual</u>, <u>upright</u> and it is <u>diminished</u>.