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EPI·STEM

Light Part 1

Suitable for Senior Cycle Physics

NARRATOR: Tara Ryan, EPI•STEM, University of Limerick

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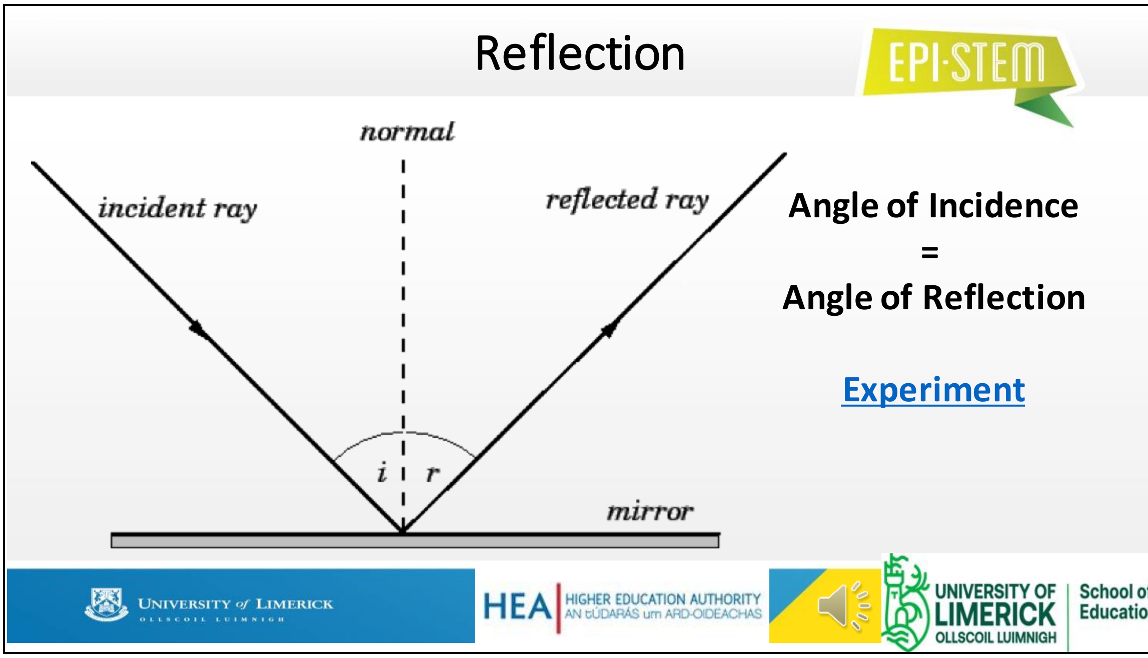
Syllabus

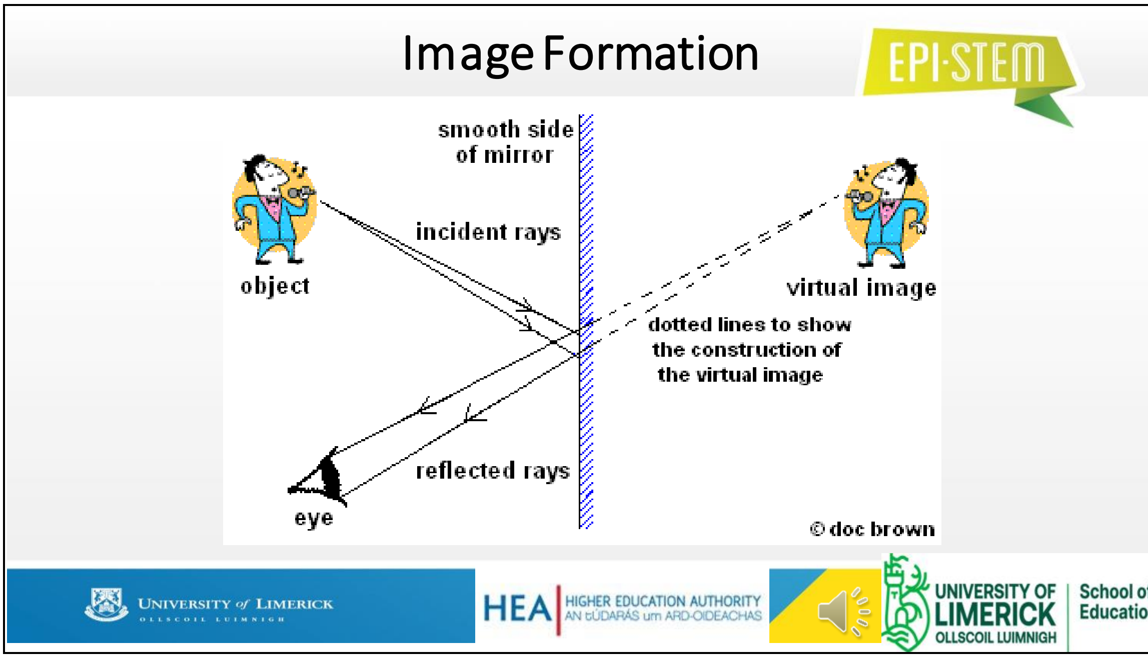
LIGHT			
Content	Depth of Treatment	Activities	STS
REFLECTION			
1. Laws of reflection		Demonstration using ray box or laser or other suitable method.	
2. Mirrors	Images formed by plane and spherical mirrors. Knowledge that $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $m = \frac{v}{u}$	Real-is-positive sign convention. Simple exercises on mirrors by ray tracing *or* use of formula.	Practical uses of spherical mirrors: Concave: • dentists • floodlights • projectors. Convex: • supermarkets • driving mirrors

Overview of Topics

- Reflection
- Image Formation
- Plane Mirrors
- Concave Mirrors
- Convex Mirrors
- Formulae



Just like a ball will bounce off a wall, light will reflect off of surfaces. The law of reflection states that the angle of incidence equals the angle of reflection, when the incident ray, the reflected ray, and the normal are all in the same plane. Regardless of whether light is reflected off a plane mirror, a curved mirror or a rough surface, the law of reflection will always apply.



There are two types of images that can be formed using mirrors: real and virtual. Our eyes are unable to distinguish between the two of them by just looking at them.

A real image is formed by the actual intersection of light rays. It can be formed on a screen.

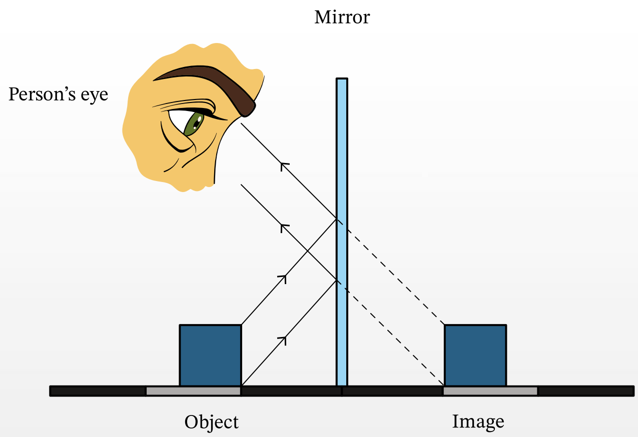
A virtual image is formed by the apparent intersection of light rays, and it cannot be formed on a screen.

Image Formation

Real Image	Virtual Image
Light rays actually meet.	Light rays only apparently meet.
Image is generally inverted.	Image is generally erect.
Image can be obtained on the screen.	Image cannot be obtained on the screen.
Image is in front of mirror & behind lens.	Image is behind mirror & in front of lens.

Listed here, are some other key differences between real and virtual images.
In real images, the image is generally inverted, whereas in virtual ones, it tends to be erect.
In real images, the image in front of the mirror and behind the lens, but in virtual ones, it is behind the mirror and in front of the lens.

Plane Mirrors

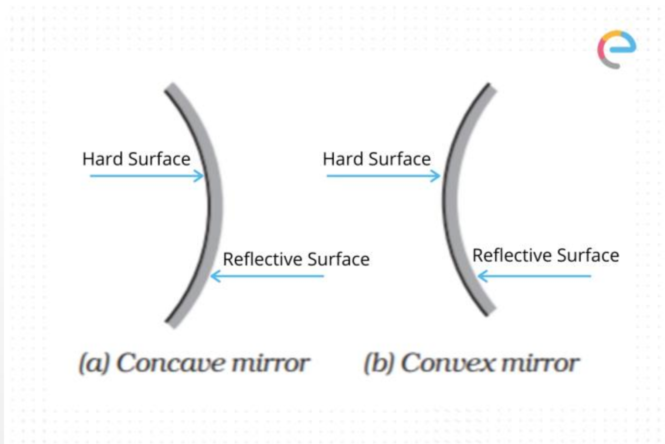


[Experiment Position of No Parallax]

A plane mirror is a mirror with a flat reflective surface. Plane mirrors form virtual images. The light rays entering our eyes are spreading apart or diverging, but our brains interpret this as the image being formed behind the mirror.

The image is always the same size as the object and the same distance behind the mirror as the object is in front of it.

Curved Mirrors

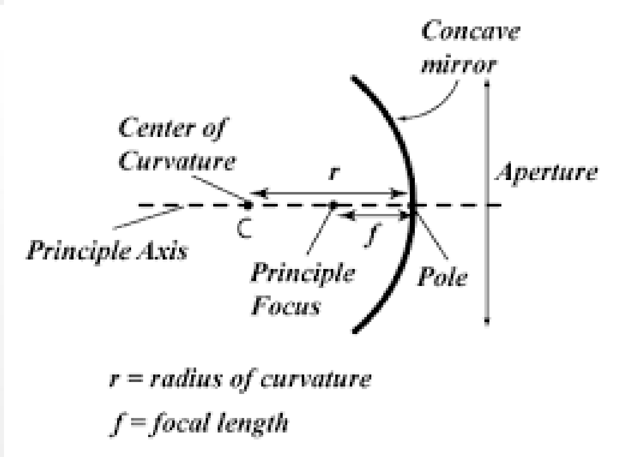


There are two types of curved mirrors: concave and convex.

A concave mirror has a reflective surface that is curved inward and away from the light source and has the same shape as a satellite dish.

A convex mirror is a mirror in which the reflective surface bulges toward the light source.

Light Ray Diagrams



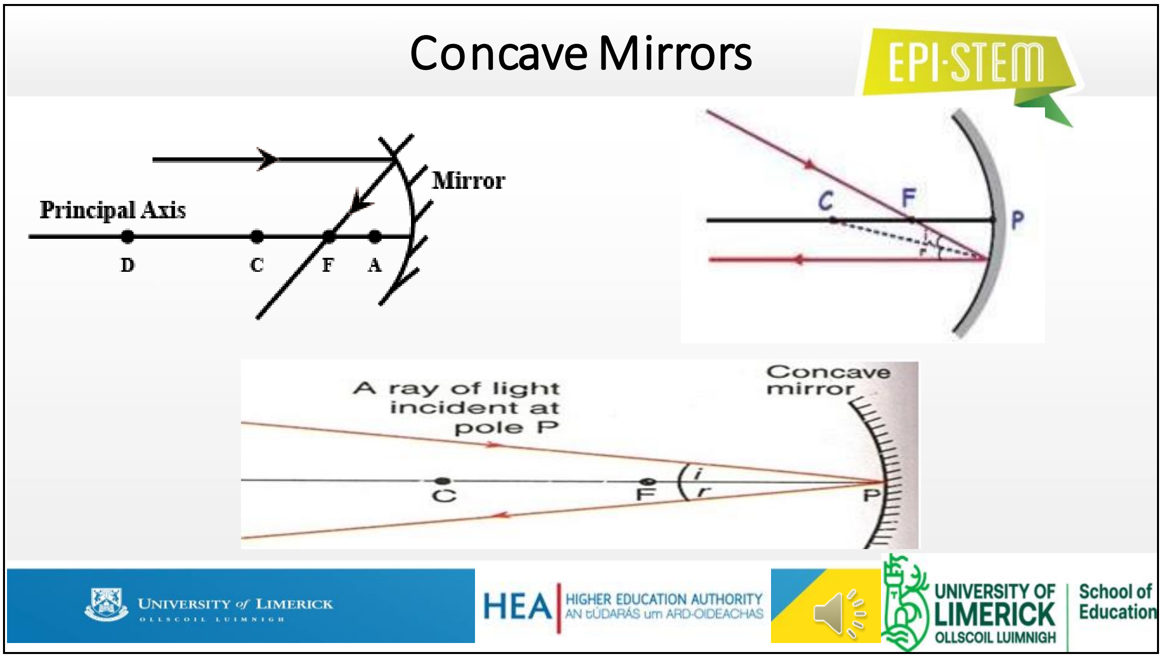
The centre of curvature (C) is the centre around which the mirror is formed.

The radius of curvature is the distance between the mirror and the centre of curvature.

The focal point (f) is the halfway point between the mirror and the centre of curvature.

The centre of curvature and the focal point lie on the principle axis.

The pole (p) is the point where the principle axis meets the mirror.

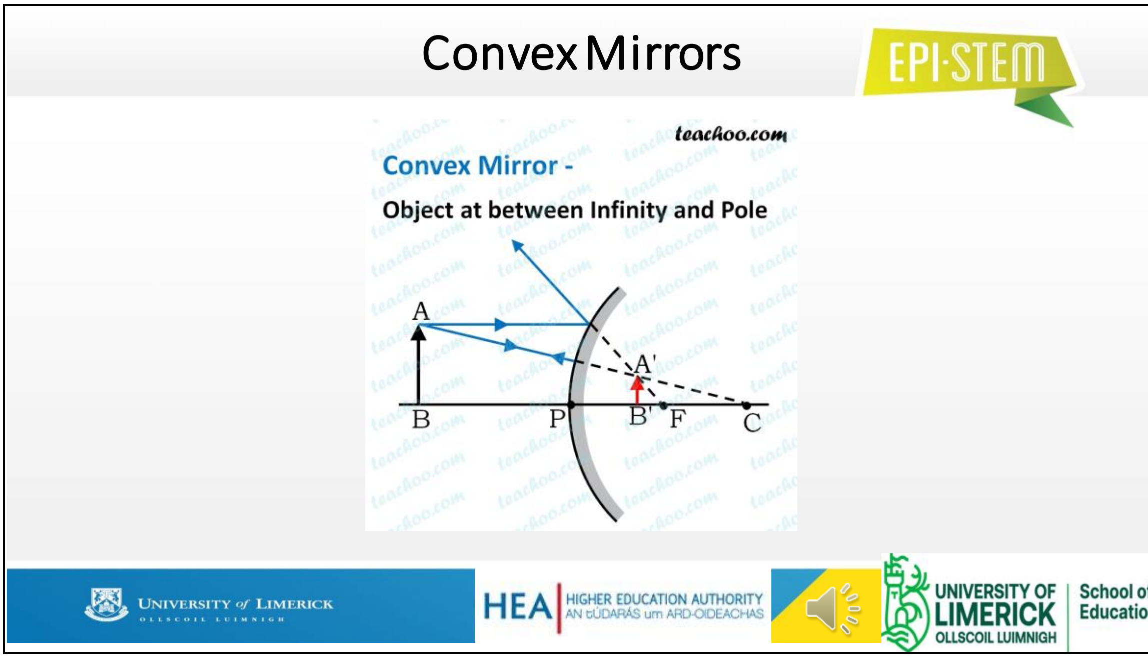


In order to determine where the image will form and what its dimensions will be, the following rules apply.

A light ray parallel to the principle axis reflects through the focal point.

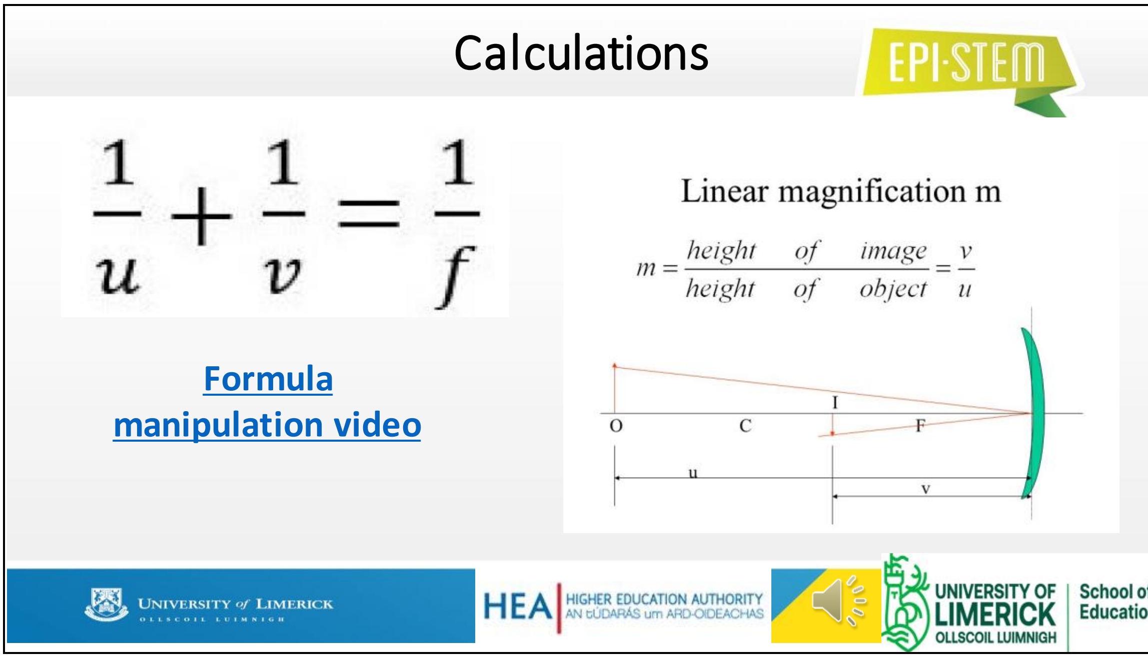
A light ray through the focal point reflects parallel to the axis.

A light ray incident at the pole clearly reflects according to the laws of reflection.



In convex mirrors, the focal point is now behind the mirror.
The image formed is always virtual, upright, and diminished.

Incident beams parallel to the axis are not reflected through it, but seem to originate from it.



Regardless of if a mirror is plane or curved, the following formulae always apply.

1 over the object distance plus 1 over the image distance is equal to 1 over the focal length.

The magnification is equal to the height of the image divided by the height of the object.

Some practical uses of concave mirrors are:

- Dentist mirrors
- Make up mirrors

Some practical examples of convex mirrors are:

- Security mirrors in shops
- Mirrors on narrow roads with sharp bends allow people to see a larger area

- External car mirrors also aid with increasing the field of vision, however the image is diminished and can lead the driver to thinking that the car behind them is further away than it actually is.

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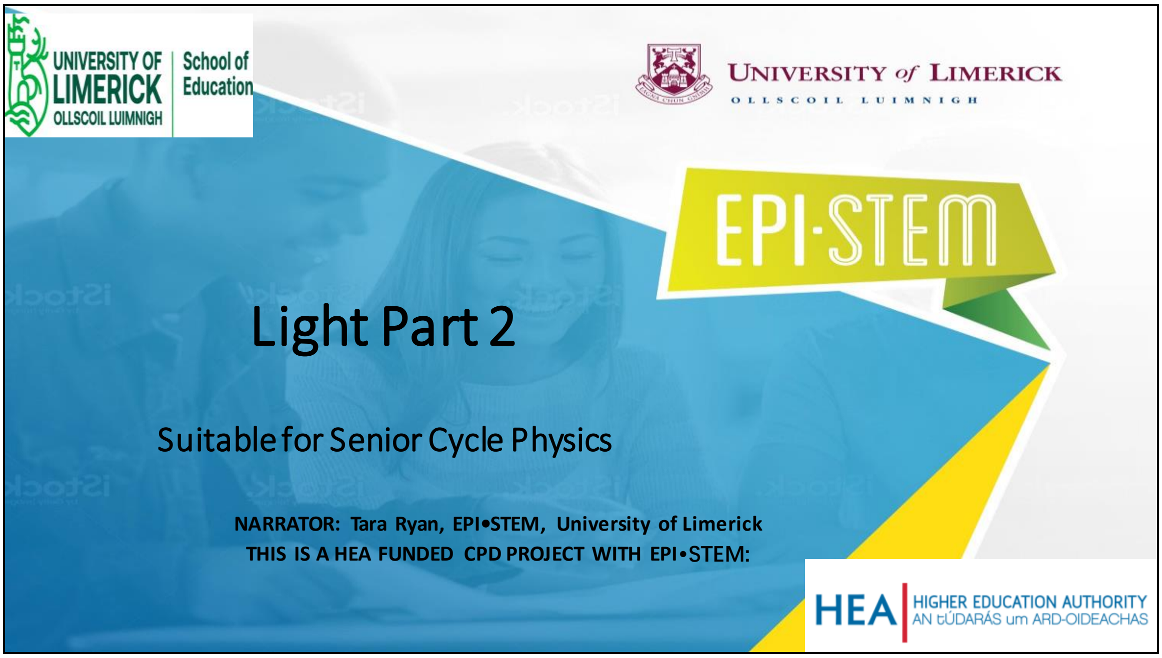
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Light Part 2
Suitable for Senior Cycle Physics
NARRATOR: Tara Ryan, EPI•STEM, University of Limerick
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Syllabus

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REFRACTION			
1. Laws of refraction	Refractive index.	Demonstration using ray box *or* laser *or* other suitable method. Appropriate calculations.	Practical examples, e.g. real and apparent depth of fish in water.
	Refractive index in terms of relative speeds.	Appropriate calculations.	
2. Total internal reflection	Critical angle. Relationship between critical angle and refractive index. Transmission of light through optical fibres.	Demonstration. Appropriate calculations.	Reflective road signs. Mirages. Prism reflectors. Uses of optical fibres: • telecommunications • medicine (endoscopes).

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Overview of Topics

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- Refraction
- Internal Reflection
- Critical Angle

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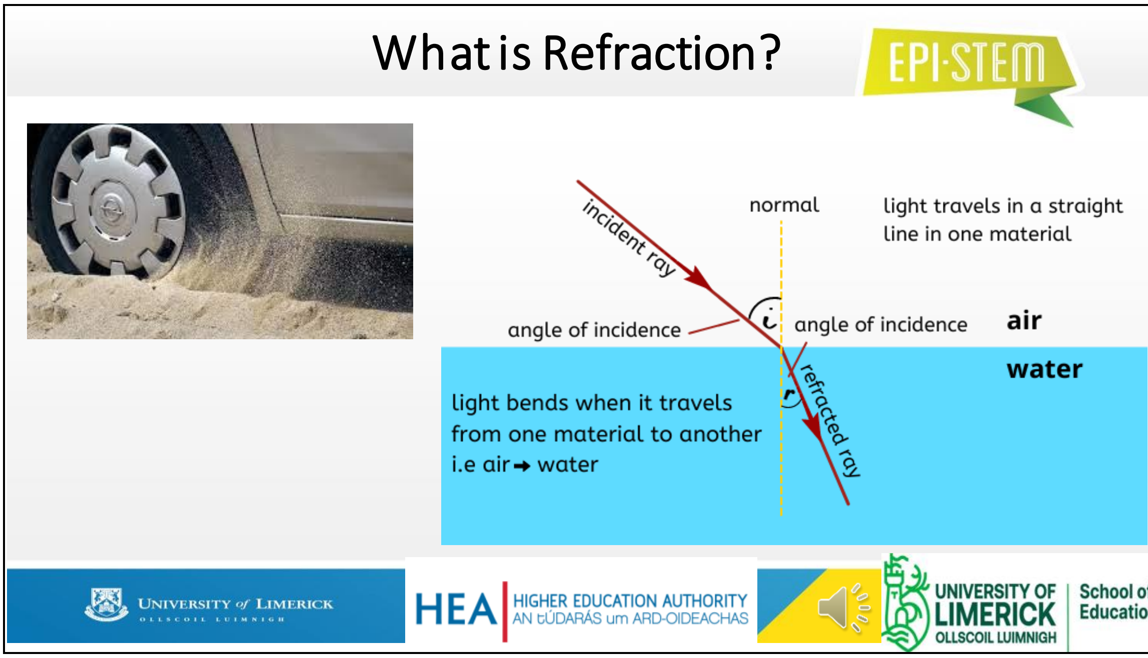
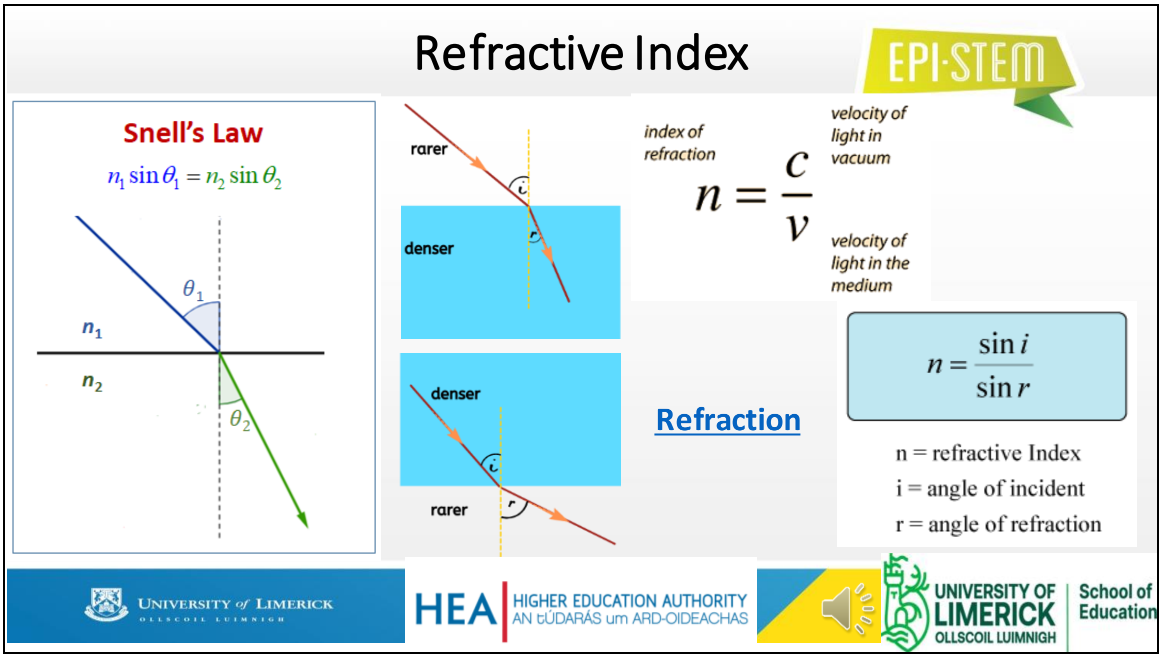


Imagine a car driving on the road, that turns down onto a beach. When the car is moving from the road to the sand, what happens? The car tends to change direction. This is because one wheel is in contact with the sand, whilst the others are still in contact with the road. The wheel on the sand slows down and the wheels on the road remain rotating at the same speed.

A similar effect happens to light when it travels from one medium to another with different densities. The light appears to bend.



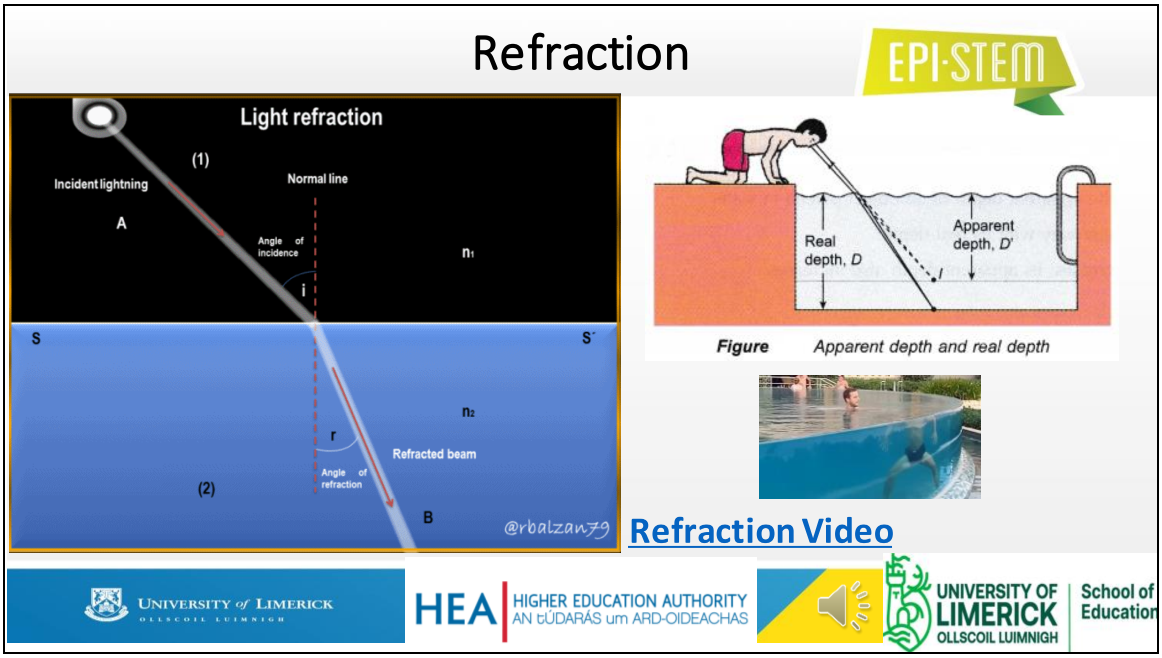
The laws of refraction state:

- The incidence ray, the refracted ray, and the normal are all along the same plane.
- For any pair of media, the sin of the angle of incidence is proportional to the sin of the angle of refraction.

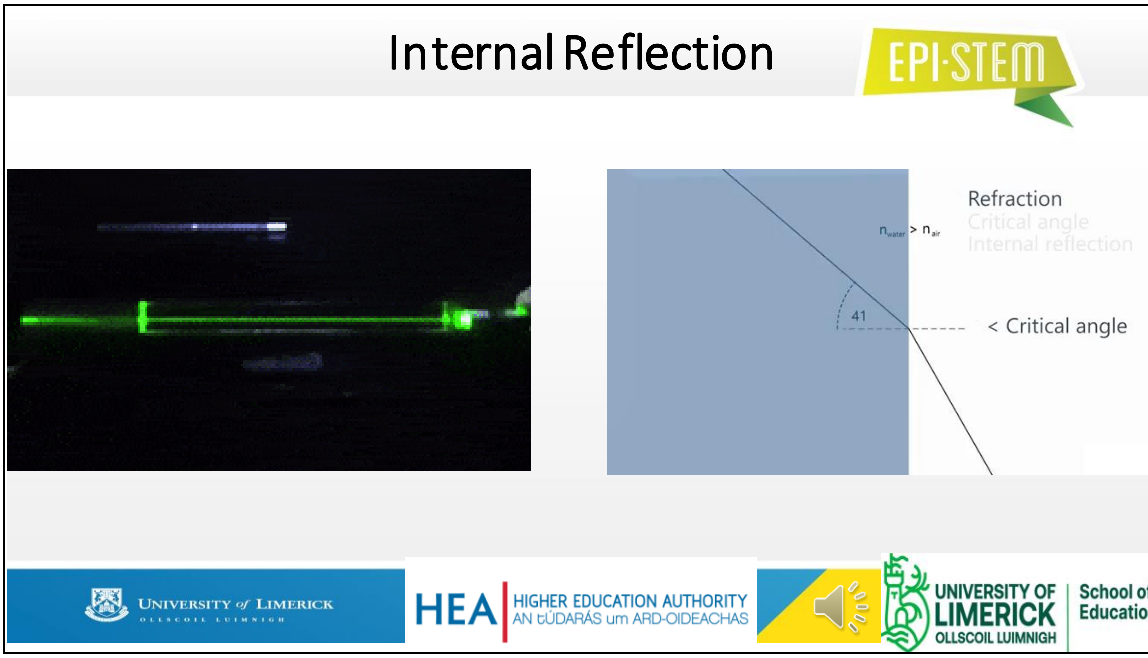
Snell's law states that:

- The refractive index (n) is equal to the sin of the incidence angle divided by the sin of the refracted angle.

- When light moves into a denser medium, it bends towards the normal.
- When light moves into a less dense medium, it bends away from the normal.



Shown here are some optical illusions caused by refraction.



Total internal reflection is the optical phenomenon in which waves arriving at the interface from one medium to another are not refracted into the second medium, but completely reflected back into the first medium.

The phenomenon of total internal reflection of light is used in many optical instruments like telescopes, microscopes, binoculars, spectroscopes, periscopes.

For total internal reflection to take place light must travel from a denser medium to a rarer medium and the angle of incidence inside the denser medium must be greater than the critical angle.

The critical angle is the angle of incidence where the angle of refraction is 90°.

Critical Angle

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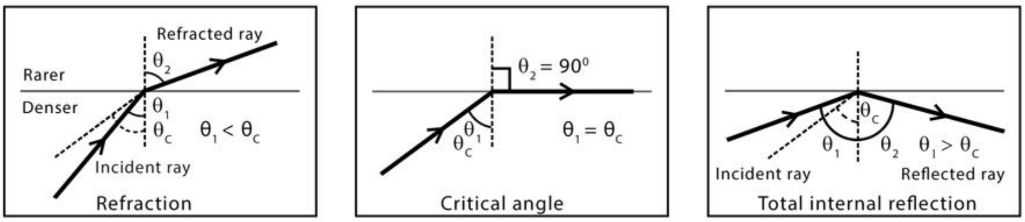
n_1 = refractive index of the denser medium n_2 = refractive index of the rarer medium

θ_1 = angle of incidence θ_2 = angle of refraction θ_C = critical angle



Snell's law of refraction

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

For critical angle, $\theta_2 = 90^0$

Therefore, $n_1 \sin\theta_1 = n_2 \sin 90^0 = n_2$

$\Rightarrow \theta_1 = \theta_C = \arcsin(n_2/n_1)$

For total internal reflection to occur, $\theta_1 > \theta_C$

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Light Part 3

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Syllabus

EPI·STEM

3. Lenses	Images formed by single thin lenses. Knowledge that $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ and $m=\frac{v}{u}$ Power of lens: $P=\frac{1}{f}$ Two lenses in contact: $P=P_1+P_2$ The eye: optical structure; short sight, long sight, and corrections.	Simple exercises on lenses by ray tracing *or* use of formula.	Use of lenses. Spectacles.

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Overview of Topics

EPI·STEM

- Lenses
- Converging Lens
- Diverging Lens
- Formulae
- The Eye
- Glasses

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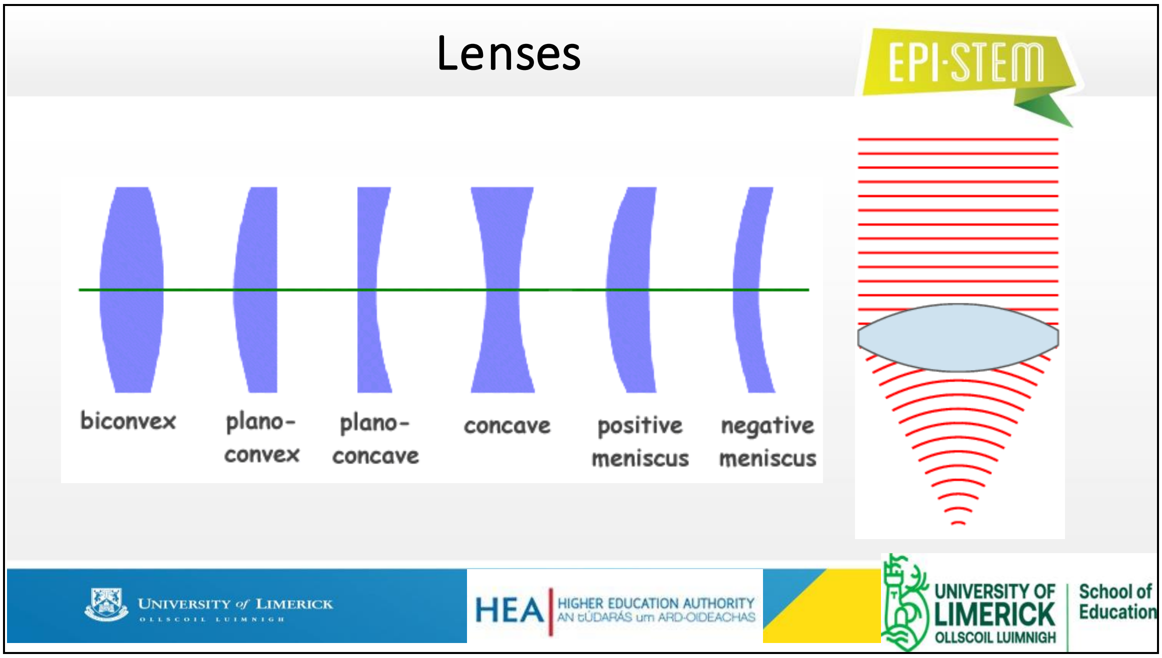
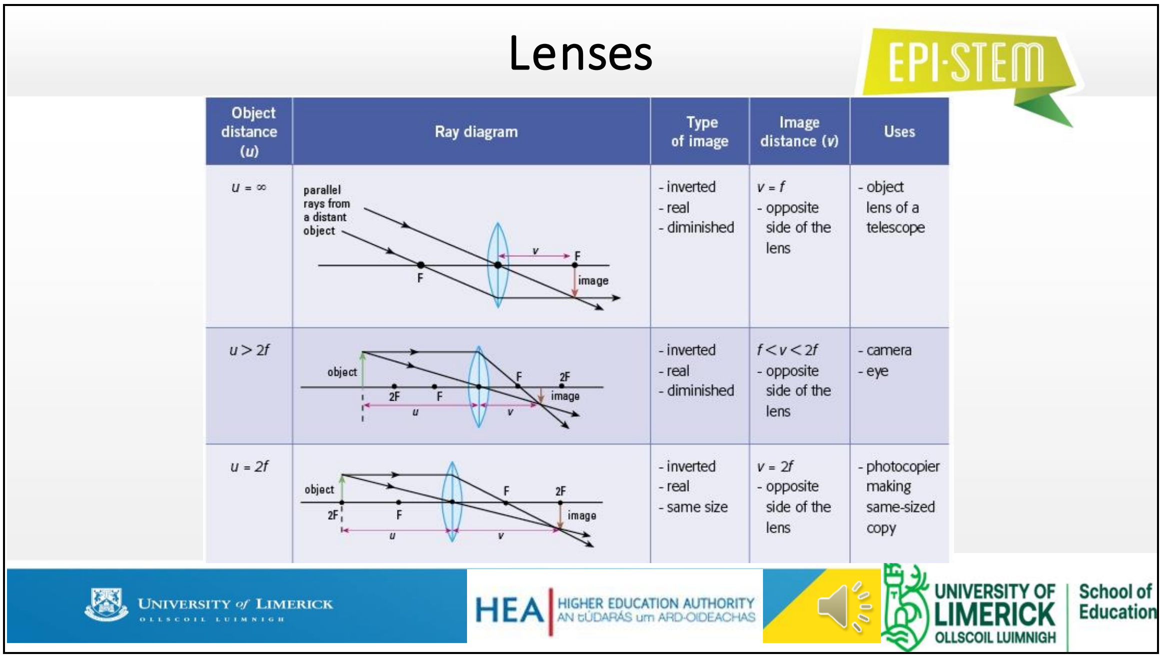


A lens is a transmissive optical device which focuses or disperses a light beam by means of refraction. A simple lens consists of a single piece of transparent material, while a compound lens consists of several simple lenses, usually arranged along a principle axis, shown here in green.

Lenses are typically used to focus light, as shown in the image on the right.

Most lenses are *spherical lenses*: their two surfaces are parts of the surfaces of spheres. Each surface can be *convex* (bulging outwards from the lens), *concave* (depressed into the lens), or *planar* (flat).

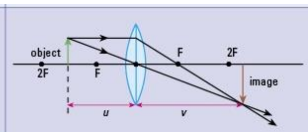
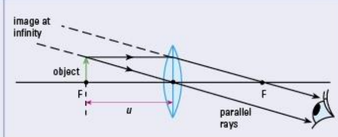
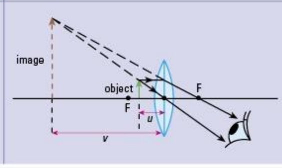


Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$u = \infty$	parallel rays from a distant object; F; v; F; image	- inverted - real - diminished	$v = f$ - opposite side of the lens	- object lens of a telescope
$u > 2f$	object; 2F; F; u; v; F; 2F; image	- inverted - real - diminished	$f < v < 2f$ - opposite side of the lens	- camera - eye
$u = 2f$	object; 2F; F; u; v; F; 2F; image	- inverted - real - same size	$v = 2f$ - opposite side of the lens	- photocopier making same-sized copy

Shown here are some ray diagrams for spherical lenses.

A light ray which strikes the optic centre will pass straight through the lens.
A ray which strikes the lens travelling parallel to the axis passes through the focus at the other side of the lens.
A ray which passes through the focus and then strikes the lens emerges parallel to the principle axis.

Lenses

$f < u < 2f$		- inverted - real - magnified	$v > 2f$ - opposite side of the lens	- projector - photograph enlarger
$u = f$		- upright - virtual - magnified	- image at infinity - same side of the lens	- to produce a parallel beam of light, e.g. a spotlight
$u < f$		- upright - virtual - magnified	- image is behind the object - same side of the lens	- magnifying glass

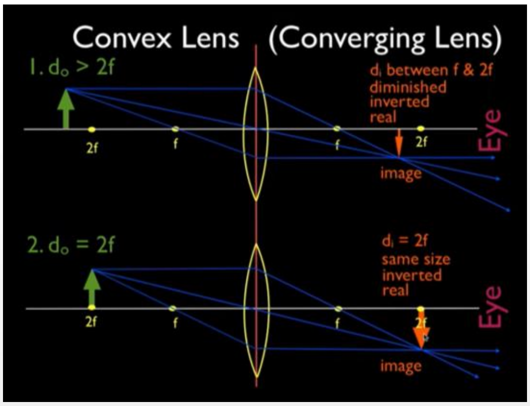
Just like with mirrors, lenses can produce two different types of images.

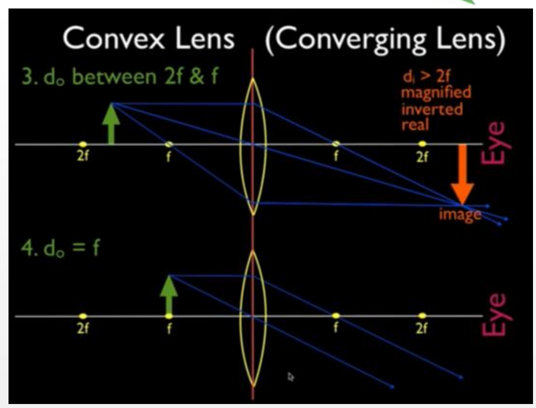
A real image is produced by the actual intersection of rays and can be located on a screen.

A virtual image is formed by the apparent intersection of rays and cannot be located on a screen.

Converging Lens

[Video]





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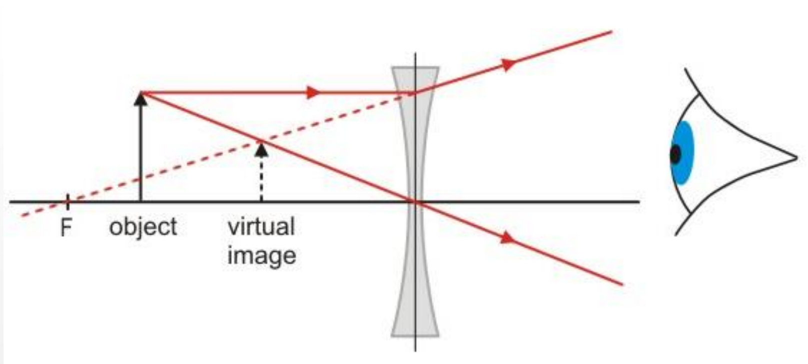
A convex or converging lens is a lens that converges rays of light that are traveling parallel to its principal axis. Converging lenses can be identified by their shape; they are relatively thick across their middle and thin at their upper and lower edges.

If the object is outside the focus, the image is real and located at the opposite side of the lens to the object. The image is inverted.

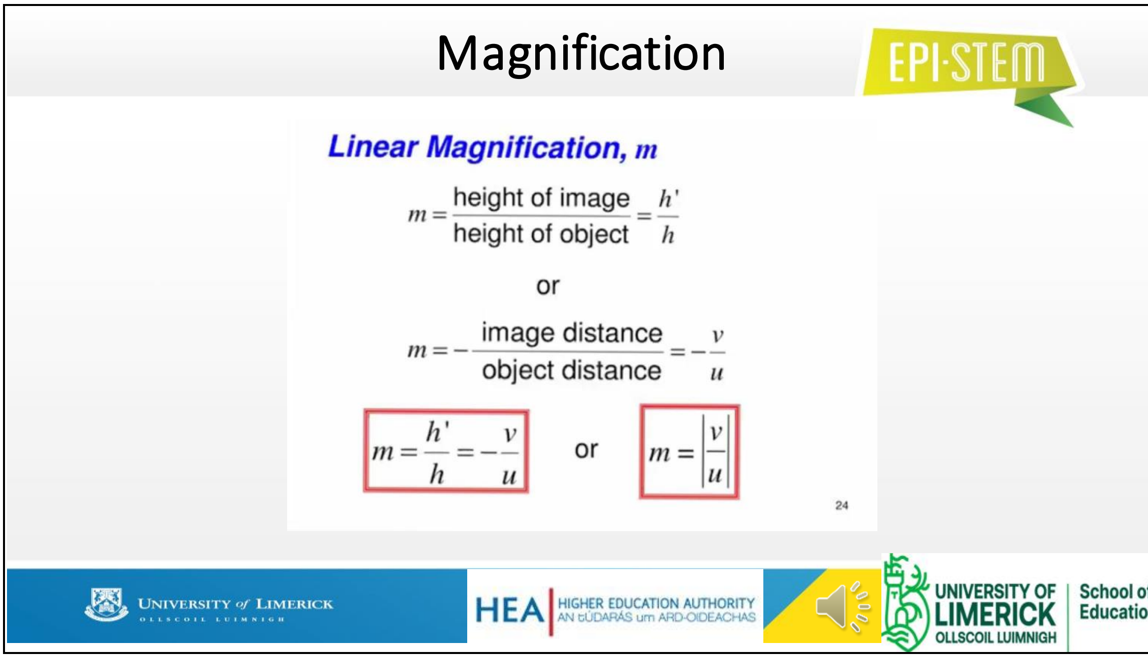
If the object is inside the focus, the image is virtual and located at the same side of the lens as the object. The image is upright.

Diverging Lens



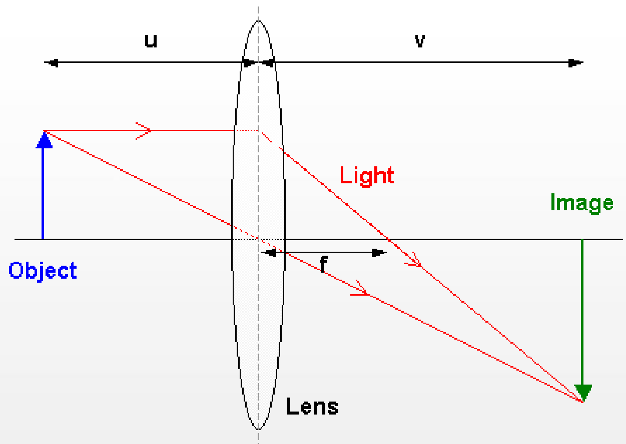
A concave lens is a lens that possesses at least one surface that curves inwards. It is a diverging lens, meaning that it spreads out light rays that have been refracted through it. A concave lens is thinner at its centre than at its edges.

A diverging lens will always create an image that is virtual, upright, and diminished.



The formula for any lens magnification is shown here, where v is the image distance, u is the object distance, and m is the magnification, which is unitless.

Lens Formula



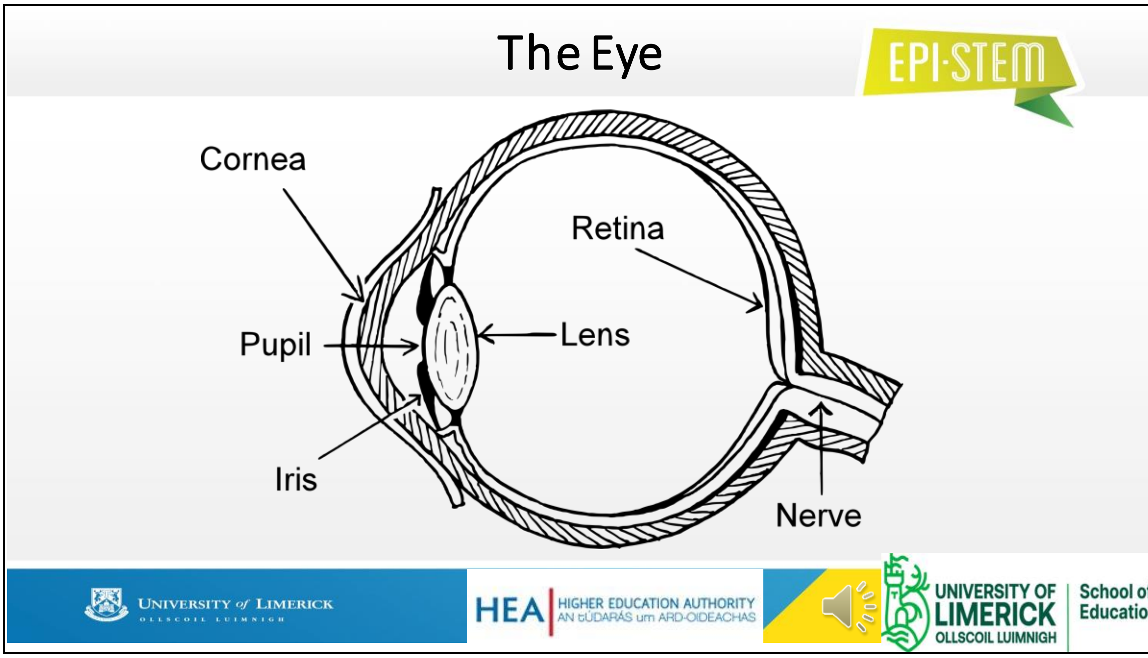
$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Distance	+	-
u	Real	Virtual
v	Real	Virtual
f	Convex	Concave

The formula for a convex lens is shown here where f is the focal length of a lens.

For a convex lens, f is positive and for a concave lens, f is negative.

When the image is real, v will be positive, and when the image is virtual, v will be negative.



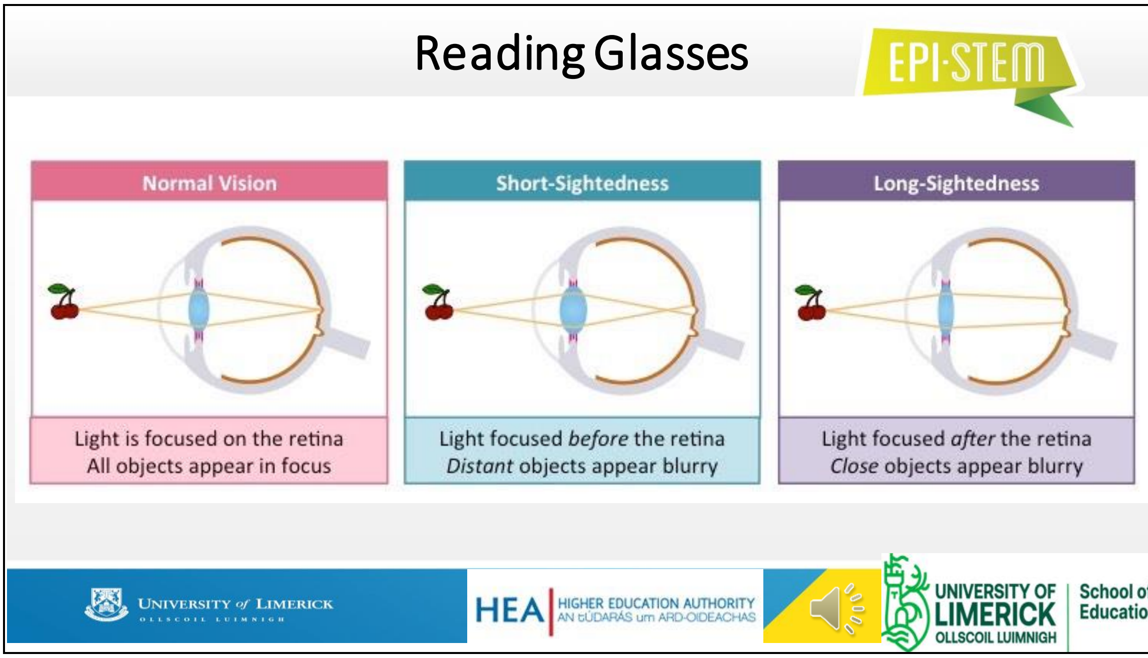
When light passes through the front of the eye an image is formed on the retina. Light energy is then converted into electrical energy to carry a message along the optic nerve to the brain.

Through the lens, light that enters the eye strikes the retina. A muscle controls how the lens is shaped and how long its focal length is. This enables us to concentrate on nearby or faraway items.

The iris regulates how much light is let past the pupil. The pupil enlarges to let in more light and contracts to let less through.
The image formed on the retina is inverted, but the brain corrects our interpretation of it.

Image retention is when an image formed on the retina persists for a short time after the object is removed. This is one of the principles behind films.

The blind spot is the area where the optic nerve leaves the eye and is not light sensitive.



A short sighted person can see nearby objects clearly, but cannot bring distant objects into focus.
Short sight can be corrected with a concave lens.

A long sighted person can see distant objects clearly, but cannot bring nearby objects into focus.
Long sight can be corrected with a convex lens.

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Light Part 4 Experiments

Suitable for Senior Cycle Physics

NARRATOR: Tara Ryan, EPI•STEM, University of Limerick
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Syllabus

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LIGHT: Experiments

1. Measurement of the focal length of a concave mirror.
2. Verification of Snell's law of refraction.
3. Measurement of the refractive index of a liquid *or* a solid.
4. Measurement of the focal length of a converging lens.
5. Measurement of the wavelength of monochromatic light.

Overview of Topics

- Measure Wavelength of Monochromatic Light
- Measure Focal Length of Concave Mirror
- Measure Focal Length of Converging Lens
- Verification of Snell's Law of Refractive Index
- Measure Refractive Index of a Liquid
- Demo: **Young's Double Slit Experiment**

Measurement of Wavelength of Monochromatic Light

Experiment Notes

Microsoft Edge PDF Document

Precautions

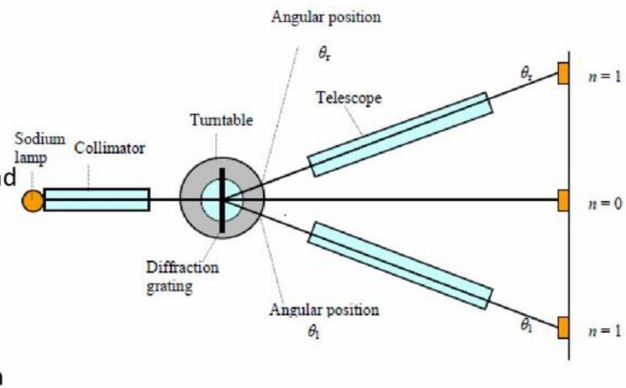
1. Make sure the grating is perpendicular to the collimator.
2. Repeat with several orders and find an average wavelength

Measurements

1. The angular separation of the fringes.
2. The distance between the lines on the grating.

Formula

nλ=dsinθ



The Spectrometer

<u>Adjustments</u>: Focus the telescope on a distant object.
Focus the collimator until a sharp mage of the slit is seen.
Level the table.

Measurement of Focal Length of Concave Mirror

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Experiment Notes

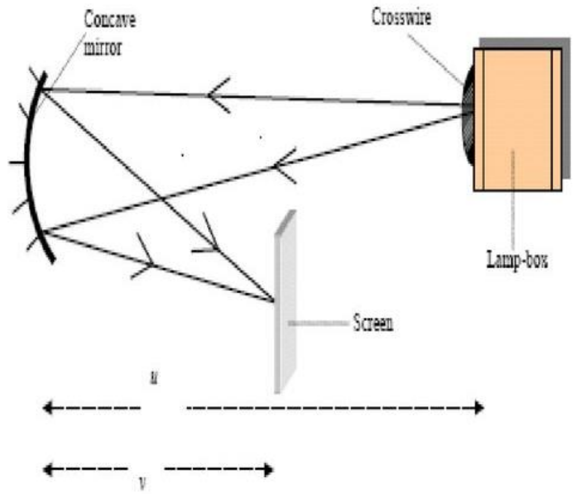
Microsoft Edge PDF Document

Find a rough value for f.

Measure object distance u and image distance v.

Find f from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Plot 1/u against 1/v. Where the graph cuts the axes gives a value for 1/f.



Precautions

•Avoid parallax measuring distances

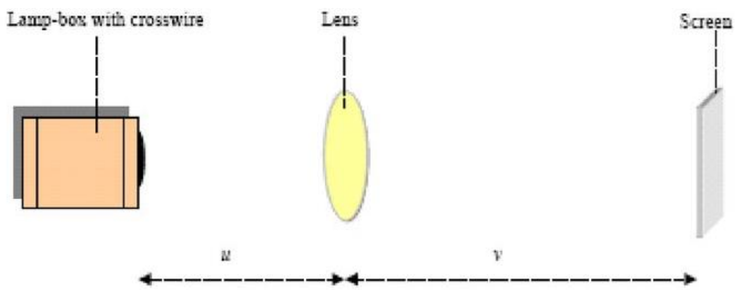
•Make u greater than the rough valve for f.

Measurement of Focal Length of Converging Lens

EPI·STEM

Experiment Notes

Microsoft Edge PDF Document



Find a rough value for f.
Measure object distance u and image distance v.
Find f from

Plot 1/u against 1/v. Where the graph cuts the axes gives a value for 1/f.

Precautions
Avoid parallax measuring distances
Make u greater the than the rough valve for f.

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Verification of Snell's Law of Refraction

Experiment Notes

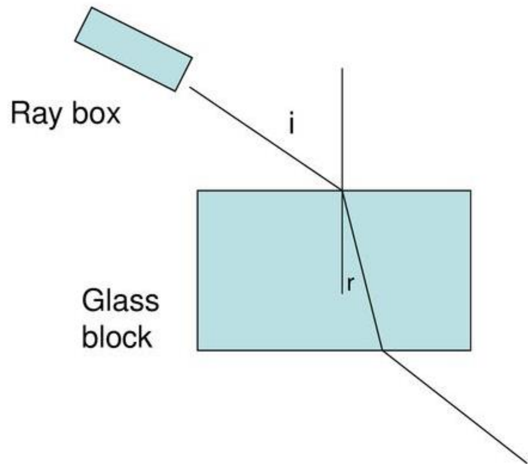
Microsoft Edge PDF Document

Graph Sin i (y axis) and Sin r (x axis)

Refractive index is the slope

Precautions

- Don't have angle i too small to reduce percentage error
- Use a sharp pencil to draw the lines



Measurement of Refractive Index of a Liquid

Experiment Notes

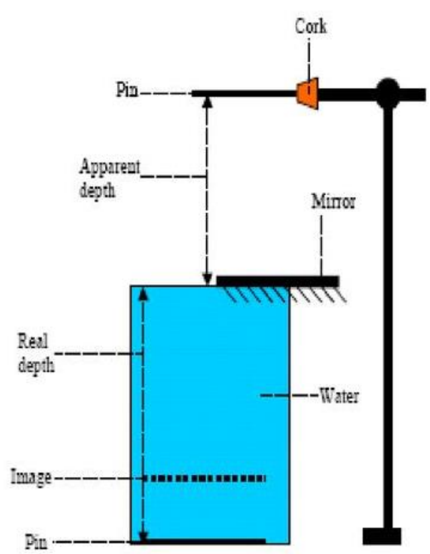
Microsoft Edge PDF Document

Measure the real depth of the container and the distance from the back of the mirror to the pin in the cork.

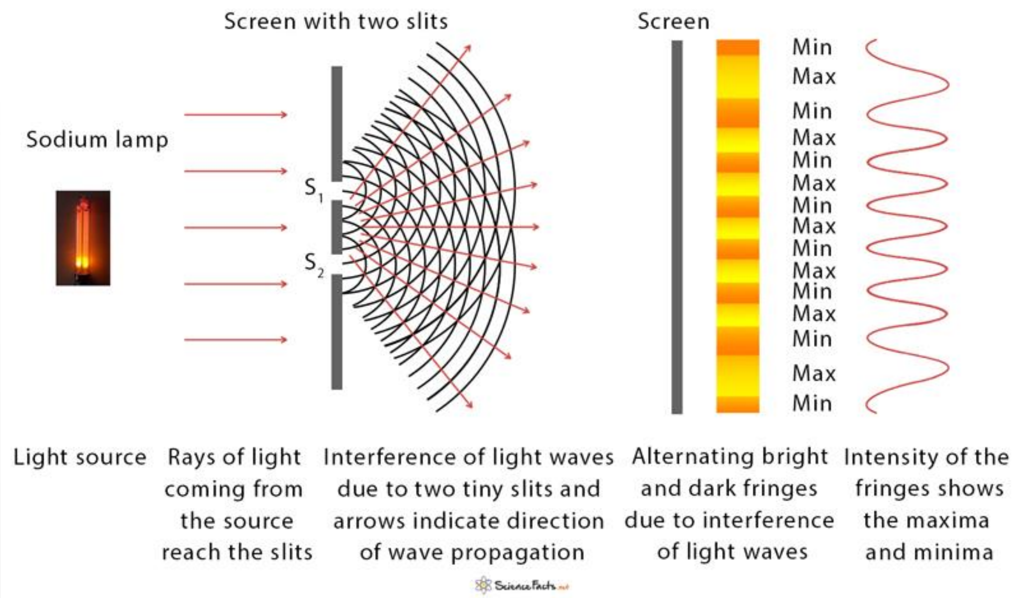
n = real depth / apparent depth

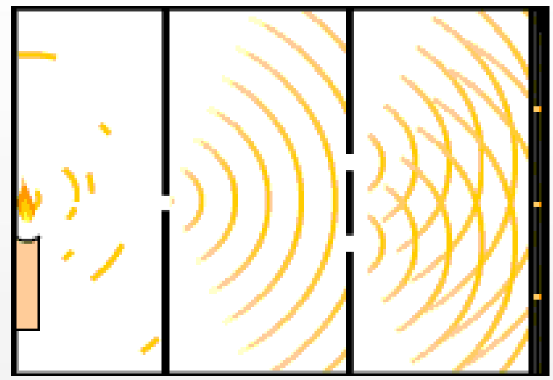
Precautions

- Repeat with various containers of differing heights and get an average.
- Make sure the water goes to the back of the mirror.



Demo: To Show Light is a Wave: Young's Double Slit Experiment





Bibliography

- https://slideplayer.com/slide/16876041/
- https://slideplayer.com/slide/16268280/
- https://www.reddit.com/r/xENTJ/comments/m1q8rf/youngs_double_slit_experiment_proving_light/
- https://physics.stackexchange.com/questions/99055/double-slit-experiment-and-representation-of-light-waves

Contact Details

Register for on-line CPD resources: https://epistem.ie
EPI•STEM project: Resources

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Email: helen.fitzgerald@ul.ie

This on-line CPD project [HEA funded] is an initiative with EPI•STEM for science and mathematics secondary teachers in Ireland. The research-led development team include:

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PHYSICS EXPERIMENTS

(LIGHT)

'In the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.' - Albert Einstein

www.psi-net.org

LEAVING CERTIFICATE PHYSICS

LISTED EXPERIMENTS

CONTENTS

LIGHT

***Measurement of the focal length of a concave mirror* 4**

***Verification of Snell's law of refraction*.. 6**

***Measurement of the refractive index of a liquid*.. 8**

***Measurement of the focal length of a converging lens* 10**

***Measurement of the wavelength of monochromatic light*... 12**

***(using the laser)* 14**

Experiment at Higher Level only*

NOTE

For examination purposes any valid method will be acceptable for describing a particular experiment unless the syllabus specifies a particular method in a given case.
Students will be expected to give details of equipment used, assembly of equipment, data collection, data manipulation including graphs where relevant. Students will also be expected to know the conclusion or result of an experiment and appropriate precautions.

SAFETY

1. The Leaving Certificate Physics syllabus states on page three:

   'Standard laboratory safety precautions must be observed, and due care must be taken when carrying out all experiments.
   The hazards associated with electricity, EHT, lasers etc. should be identified where possible, and appropriate precautions taken. The careful use of sources of ionising radiation is essential. It is important that teachers follow guidelines issued by the Department of Education and Science.'

2. The guidelines referred to here consist of two books, which were published by the Department of Education in 1997. The books are

   'Safety in School Science'

   and

   'Safety in the School Laboratory (Disposal of chemicals)'

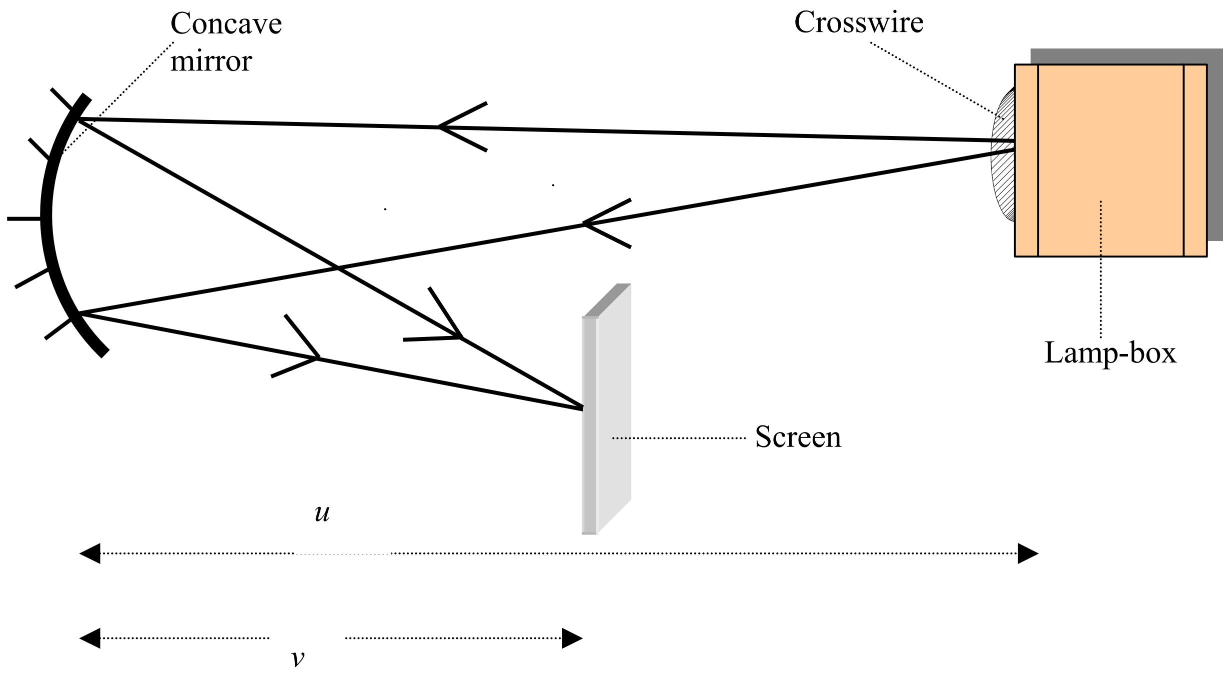
   When these books were published they were distributed to all schools. They have been revised and are available on the 'physical sciences initiative' web site at www.psi-net.org in the 'safety docs' link of the physics section.

3. Teachers should note that the provisions of the Safety, Health and Welfare at Work Act, 1989 apply to schools. Inspectors appointed under that act may visit schools to investigate compliance.

MEASUREMENT OF THE FOCAL LENGTH OF A CONCAVE MIRROR

Apparatus

Concave mirror, screen, lamp-box with crosswire.



Procedure

1. Place the lamp-box well outside the approximate focal length - see notes.
2. Move the screen until a clear inverted image of the crosswire is obtained.
3. Measure the distance u from the crosswire to the mirror, using the metre stick.
4. Measure the distance v from the screen to the mirror.
5. Calculate the focal length of the mirror using $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.
6. Repeat this procedure for different values of u.
7. Calculate f each time and then find an average value.

Results

u/cm	$\frac{1}{u}$/cm^{-1}	v/cm	$\frac{1}{v}$/cm^{-1}	$\frac{1}{f}$/cm^{-1}	f/cm

Average f =

Notes

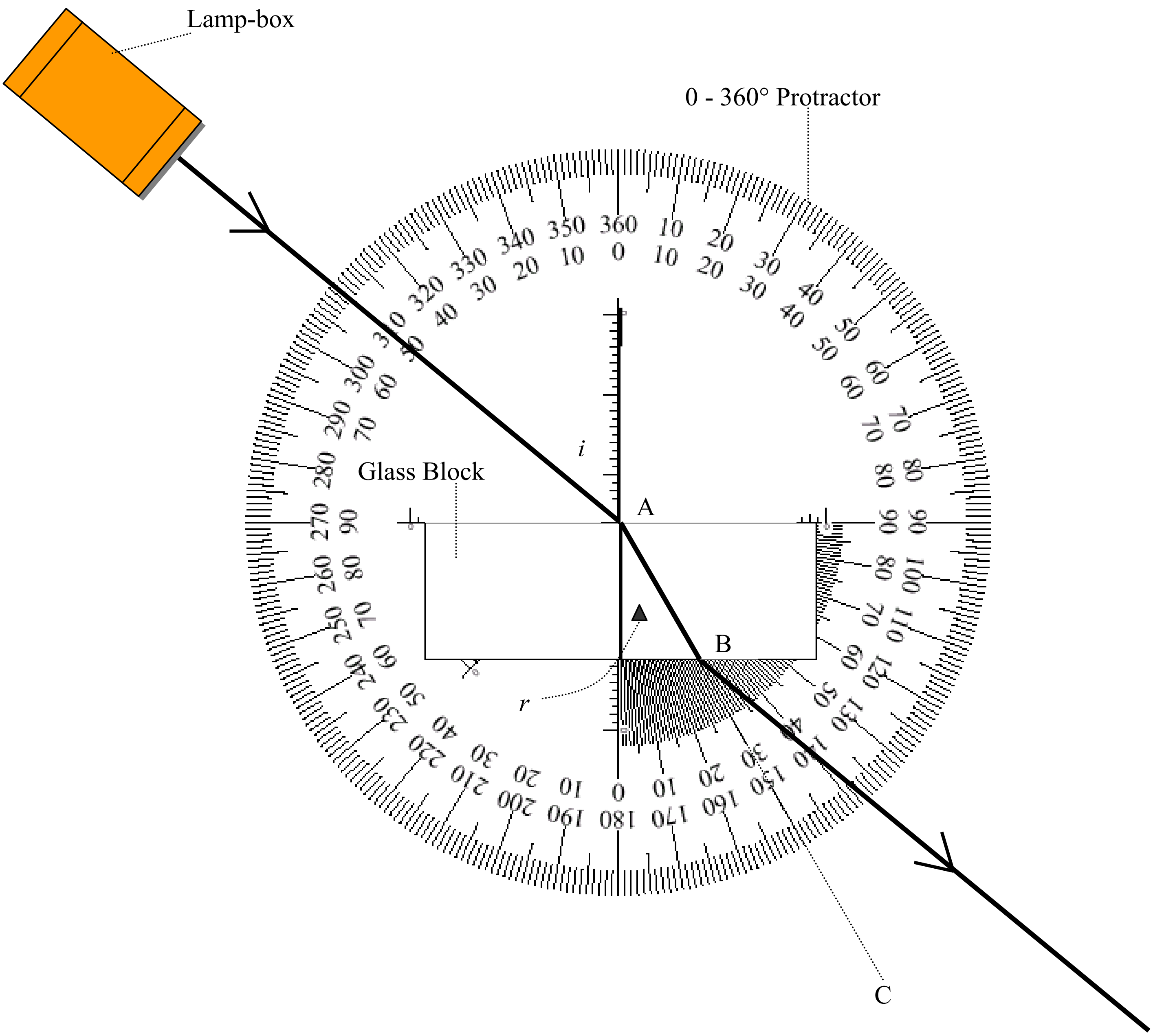
The approximate method for finding the focal length is recommended as a starting point for this experiment. The approximate method is described in the Appendix.

A microscope lamp makes a very suitable strong light source. Cover the glass of the lamp with a piece of tracing paper. Use ‘peel-and-stick’ letters to create an ‘object’ on the tracing paper.

VERIFICATION OF SNELL'S LAW OF REFRACTION

Apparatus

Glass block, lamp-box, 0-360^0 protractor, (photocopied from page 56 of Physics A Teacher's Handbook)



Procedure

1. Place a glass block on the 0-360^0 protractor in the position shown on the diagram and mark its outline.
2. Shine a ray of light from a lamp-box at a specified angle to the near side of the block and note the angle of incidence.
3. Observe the ray of light leaving the glass block and similarly mark the exact point B where it leaves the glass block.
4. Remove the glass block. Join BA and extend to C.
5. Note the angle of refraction *r*.
6. Repeat for different values of *i*.
7. Draw up a table as shown.
8. Plot a graph of sin *i* against sin *r*.

Results

i/°	r/°	$\sin i$	$\sin r$	$\frac{\sin i}{\sin r}$

Average value of $\frac{\sin i}{\sin r}$ =

A straight line through the origin verifies Snell's law of refraction i.e. $\sin i \propto \sin r$.

The slope of the line gives a value for the refractive index of glass.

The refractive index of glass is equal to the average value of $\frac{\sin i}{\sin r}$.

Notes

Look directly down through the glass or plastic block to measure the angle of refraction.

Print the 360° protractor directly from page 56 of 'Physics A Teachers Handbook' to obtain the clearest delineation of the marked angles.

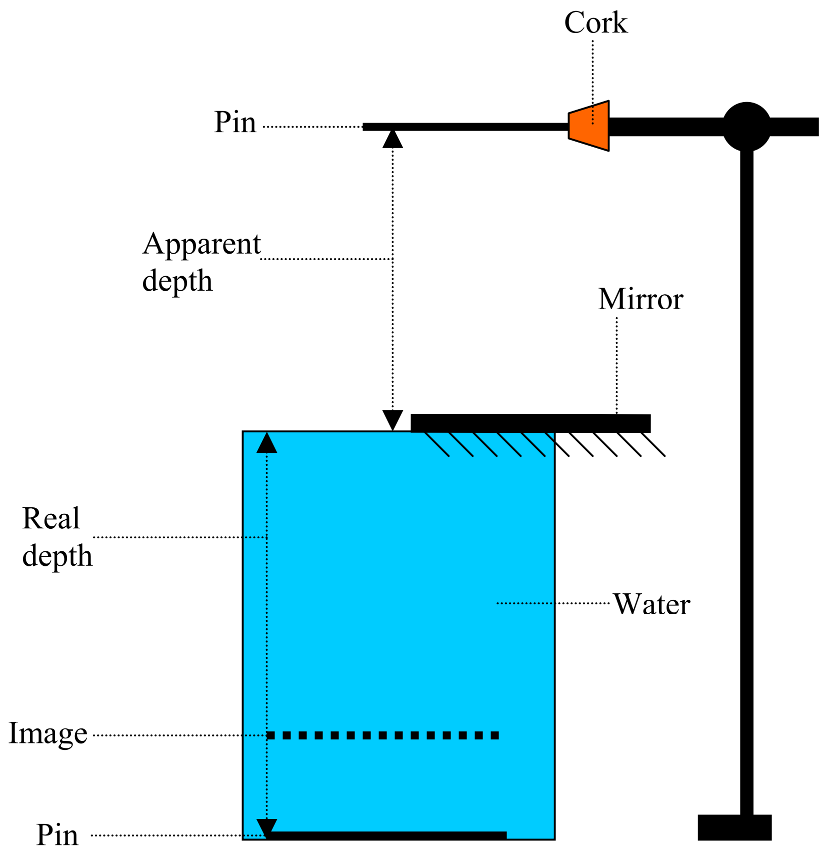
A semi-circular glass block can be used instead of the rectangular block.

A commercial model of the 360° protractor is also available. The model has a 'rotating' protractor housed in a horizontal rectangular base.

MEASUREMENT OF THE REFRACTIVE INDEX OF A LIQUID

Apparatus

Plane mirror, two pins, cork, retort stand, large containers.



Procedure

1. Fill a container to the top with water.
2. Place the plane mirror to one side on top of the container.
3. Put a pin on the bottom of the container.
4. Adjust the height of the pin in the cork above the mirror until there is no parallax between its image in the mirror and the image of the pin in the water.
5. Measure the distance from the pin in the cork to the back of the mirror – this is the apparent depth.
6. Measure the depth of the container – this is the real depth.
7. Calculate the refractive index, $n = \frac{\text{real depth}}{\text{apparent depth}}$.
8. Repeat using different size containers and get an average value for n.

Results

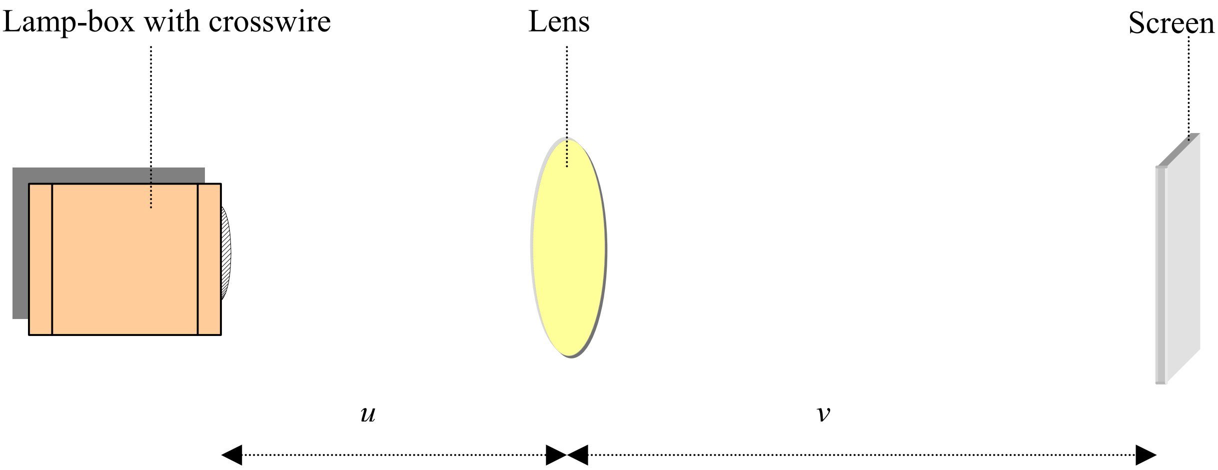
real depth/cm	apparent depth/cm	$n = \dfrac{\text{real depth}}{\text{apparent depth}}$

Average $n =$

MEASUREMENT OF THE FOCAL LENGTH OF A CONVERGING LENS

Apparatus

Converging lens, screen, lamp-box with crosswire, metre stick, retort stand.



Procedure

1. Place the lamp-box well outside the approximate focal length – see notes.
2. Move the screen until a clear inverted image of the crosswire is obtained.
3. Measure the distance u from the crosswire to the lens, using the metre stick.
4. Measure the distance v from the screen to the lens.
5. Calculate the focal length of the lens using $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.
6. Repeat this procedure for different values of u.
7. Calculate f each time and then find the average value.

Results

u/cm	$\frac{1}{u}$/cm^{-1}	v/cm	$\frac{1}{v}$/cm^{-1}	$\frac{1}{f}$/cm^{-1}	f/cm

Average f =

Notes

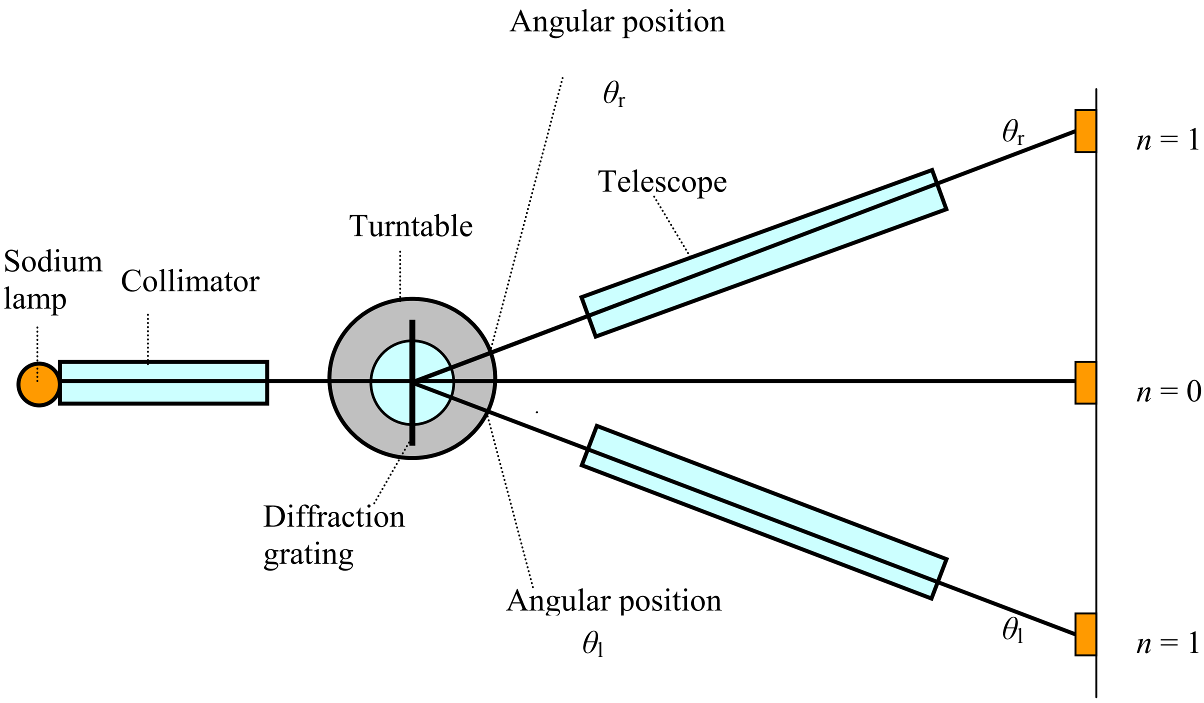
The approximate method for finding the focal length is recommended as a starting point for this experiment. The approximate method is described in the Appendix.

A microscope lamp makes a very suitable strong light source that can be used in daylight. Cover the glass of the lamp with a piece of tracing paper. The tracing paper can be attached with some bluetack. Use ‘peel-and-stick’ letters to create an ‘object’ on the tracing paper. If the ‘object’ is a simple three-letter word then the inversion of the image will be obvious.

MEASUREMENT OF THE WAVELENGTH OF MONOCHROMATIC LIGHT

Apparatus

Sodium lamp, spectrometer and diffraction grating (300 lines per mm).



Procedure

1. Adjust the eyepiece of the telescope so that the crosswires are sharply focused.
2. Focus the telescope for parallel light using a distant object. There should be no parallax between the image seen in the telescope and the crosswires seen through the eyepiece.
3. Place the sodium lamp in front of the collimator.
4. Level the turntable of the spectrometer if necessary.
5. Looking through the telescope, focus the collimator lens and adjust the width of the slit until a clear narrow image is seen.
6. Place the diffraction grating on the turntable at right angles to the beam.
7. Move the telescope to the right until the cross wires are centred on the first bright image. Take the reading θ_r from the scale on the turntable. (To see the scale more easily shine a lamp on it and use a magnifying lens).
8. Move the telescope back through the centre and then to the first bright image on the left.
9. Take the reading θ_l from the scale.
10. Calculate θ using $\theta = \dfrac{\theta_r - \theta_l}{2}$.

11. Calculate the distance d between the slits using $d = \frac{1}{N}$ where N is the number of lines per metre on the grating.
12. Calculate the wavelength λ using $n\lambda = d \sin\theta$.
13. Repeat this for different orders (n) and get an average value for the wavelength.

Results

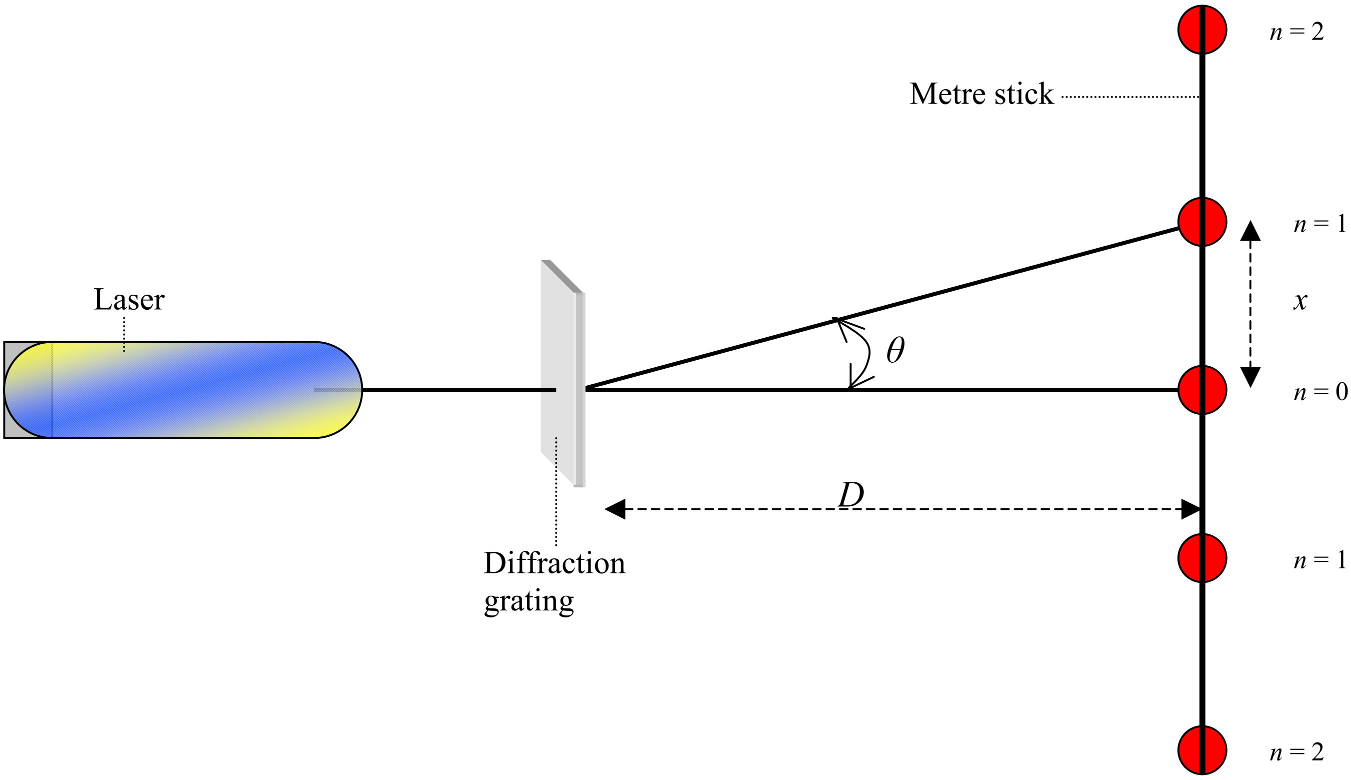
n	θ_r/ °	θ_l/ °	$\theta = \dfrac{\theta_r - \theta_l}{2}$ / °	λ/m

Average λ =

MEASUREMENT OF THE WAVELENGTH OF MONOCHROMATIC LIGHT (using the laser)

Apparatus

Laser, diffraction grating (600 lines per mm), 2 metre sticks.



Procedure

1. Clamp a metre stick horizontally in a stand.
2. Allow the laser beam to hit the metre stick normally (at 90 °).
3. Move the metre stick sideways until the spot is on the 50 cm mark.
4. Place the grating between the laser and the metre stick, at right angles to the beam.
5. Observe the interference pattern on the metre stick – a series of bright spots.
6. Calculate the mean distance x between the centre (n=1) bright spot and the first (n =1) bright spot on both sides of centre.
7. Measure the distance D from the grating to the metre stick.
8. Calculate θ using $\tan\theta = \frac{x}{D}$.
9. Calculate the distance d between the slits, using $d = \frac{1}{N}$, where N is the number of lines per metre on the grating.
10. Calculate the wavelength λ using $n\lambda = d\sin\theta$.
11. Repeat this procedure for different values of n and get the average value for λ.

Results

n	x/m	D/m	θ/ °	λ/m

Average λ =

Light Exam Questions

Suitable for Senior Cycle Physics

NARRATOR: Tara Ryan, EPI•STEM, University of Limerick
THIS IS A HEA FUNDED CPD PROJECT WITH EPI•STEM:

List of Exam Questions

Higher Level

2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
3, 13	2, 8, 14d	2	2, 10, 12c	2, 3	12c	3, 11	3, 12b	2, 12b	3	2

Ordinary Level

2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
2, 9, 14b	3, 8, 10	2, 7	3, 11	none	3, 7	2, 7	3, 12b	8	3, 12b	3, 12b

Provided here are lists of exam questions from 2012-2022 for both higher and ordinary levels.

Excluded from this list was:
- Q5s, as they were considered too short
- Qs focusing on waves and sound. This resource pack focuses solely on light.

Overview of Topics

Higher Level

- ❑ Experiment Question
- ❑ Theory Question

Ordinary Level

- ❑ Experiment Question
- ❑ Theory Question

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2022 Q3 HL

In an experiment to verify Snell's law, a student measured the angle of incidence *i* and the angle of refraction *r* for a ray of light as it passes from air into glass. This process was repeated for six different values of *i*.

The following data were recorded.

i (degrees)	30	40	50	60	70	80
r (degrees)	19	27	32	36	40	44

(*i*) Draw a labelled diagram of how the apparatus was arranged in this experiment.

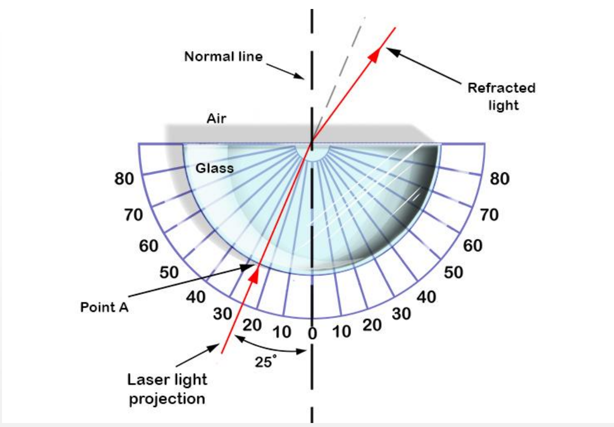
(*ii*) Describe how the student determined the angle of refraction. (18)

(*iii*) Draw a suitable graph to verify Snell's law.

(*iv*) Use your graph to calculate the refractive index of the glass.

(*v*) What would be observed if the angle of incidence was zero degrees? (22)

(i) Labelled Diagram



<u>9 marks in total.</u>

Must include:

- A transparent block (3 marks).
- A ray box, lasers, or pins (3 marks).
- A detail such as paper, a ruler, or protractor (3 marks).

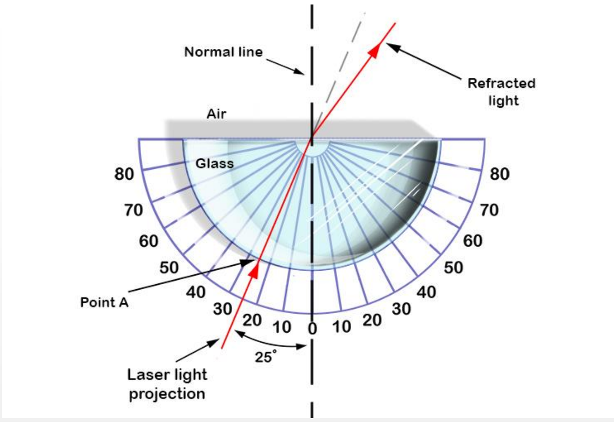
For three marks each, students must include:

- A transparent block
- A ray box, lasers, or pins
- And a detail such as paper, a ruler, or protractor.

The diagram should show a ray of light from a source entering a transparent block and exiting it as if it appears to have been bent. A normal line and protractor can indicate the difference in angles of the incidence and refraction.

As always, each component in the diagram should be labelled clearly. If not, one mark will be taken away.

(ii) Determine the Angle of Refraction



<u>9 marks in total.</u>

Include any 3 points:

- Incident ray (3 marks).
- Refracted ray (3 marks).
- Normal line at point of incidence (3 marks).
- Measure angle with protractor (3 marks).

To determine the angle of refraction, a student would draw the incident beam projected on the sheet of paper, draw the refracted ray, and draw the normal line at the point of incidence.

The student would then measure the angle of refraction using a protractor.

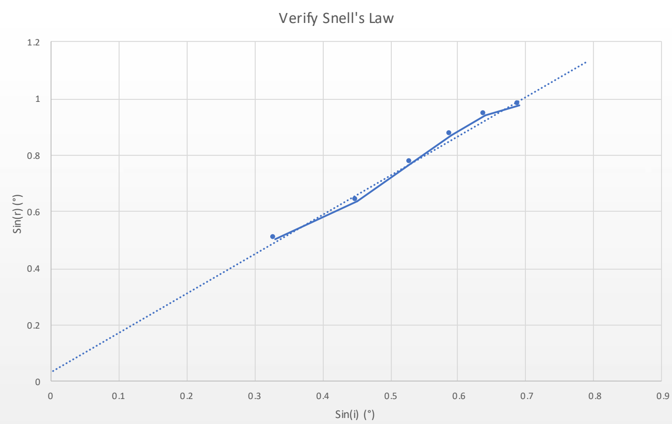
(iii) Graph to verify Snell's Law

Given		Calculate	
i (°)	r (°)	Sin(i) (°)	Sin(r) (°)
30	19	0.5	0.33
40	27	0.64	0.45
50	32	0.77	0.53
60	36	0.87	0.59
70	40	0.94	0.64
80	44	0.98	0.69

In the exam question, the angles of incidence (i) and the angles of refraction (r) are given. However, in order to correctly plot a graph that verifies Snell's law, students must first calculate the values for Sin(i) and Sin(r), as shown here.

Additionally, when drawing tables of data, the units being used (which are degrees in this case), must be clearly displayed alongside the label of the data column, rather than being repeated after each individual piece of data

(iii) Graph to verify Snell's Law



<u>9 marks in total.</u>

Must include:

- Labelled axes (3 marks).
- Correct points plotted (3 marks).
- Line of best fit (3 marks).

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When plotting a graph, the independent variable will be placed on the x-axis. This is the set of parameters that the person carrying out the experiment sets. In this case, the independent variable is Sin(i).
Therefore, the dependent variable is Sin(r) and is placed on the y-axis. This set of data is entirely dependent on the outcome of the experiment.
As always, the chart title, and both axes must be labelled, including units.
One mark will be lost for incorrect scales.

When plotting a graph, it is important to be precise and accurate when plotting the points.
These points are then connected by a ‘line of best fit’ as shown in light blue, spanning the entirety of the graph. A line of best fit, approximately has the same number of points both above and below it.

(iv) Calculate Refractive Index

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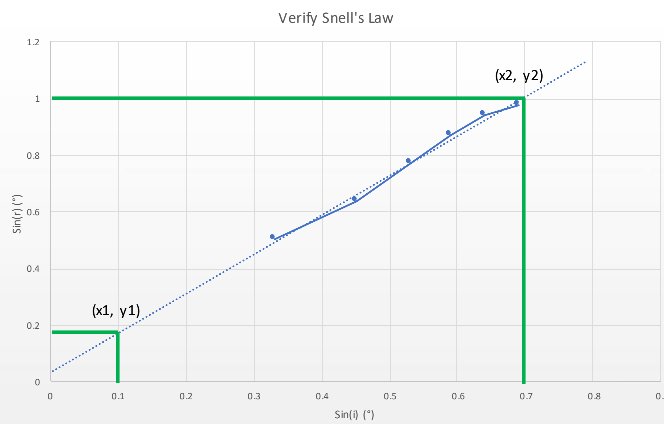

Refractive index $= Slope\ of\ line\ of\ best\ fit$

$$m = \frac{y2 - y1}{x2 - x1} \quad (3\,marks)$$

$$m = \frac{1 - 0.19}{0.7 - 0.1}$$

$$m = \frac{0.81}{0.6}$$

$$m = 1.35 \quad (3\,marks)$$

Formula Shown	Excel Calculation	Marking Scheme
1.35	1.3981	1.4

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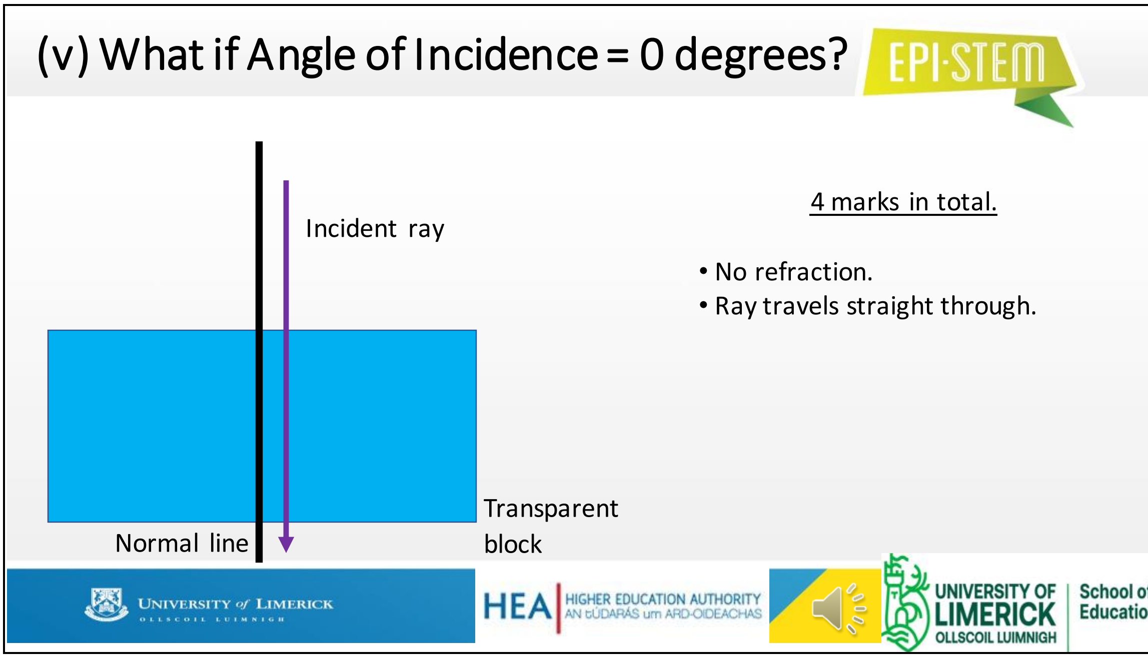
To determine the refractive index, the slope of the line of best fit must be calculated.

To do this, pick two points on the line of best fit. The further apart they are, the less error there will be.
Once these two points are determined, used the formula shown here to calculate the slope of the line.

When calculating the slope of the line, we used both the formula shown here, and an excel calculator. Comparing these values to the marking scheme, it is obvious that the values are not exactly the same. Due to hand drawn graphs not being as precise as digital ones, the examiner will allow slight variations in answers, provided that it is only a minor difference that can be approximated as being equal using rounding.



If the angle of incidence is zero degrees, then there would be no refraction, and the light beam would travel straight through the transparent block.

Overview of Topics

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Higher Level

- ✓ Experiment Question
- ❑ Theory Question

Ordinary Level

- ❑ Experiment Question
- ❑ Theory Question

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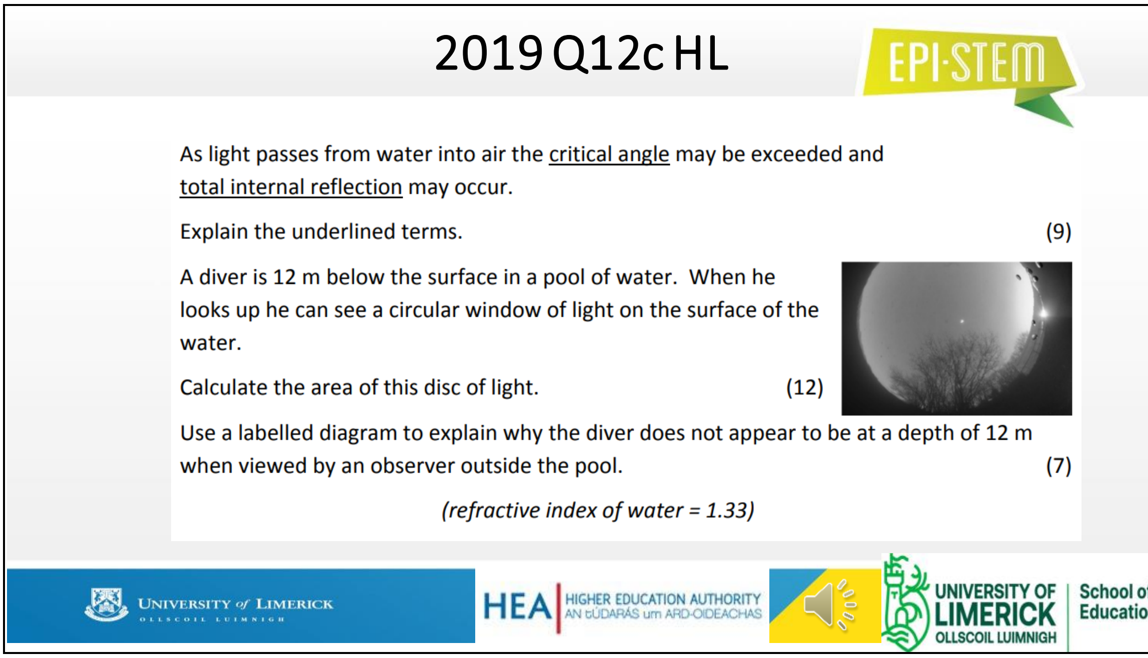


You'll notice that in earlier exam papers, the questions are either poorly labelled, or not labelled at all. To avoid confusion, we recommend that your students assign their own labels to each part of the question, as shown on the next slide.

2019 Q12c HL

As light passes from water into air the <u>critical angle</u> may be exceeded and <u>total internal reflection</u> may occur.

(i) Explain the underlined terms. (9)

A diver is 12 m below the surface in a pool of water. When he looks up he can see a circular window of light on the surface of the water.

(ii) Calculate the area of this disc of light. (12)

(iii) Use a labelled diagram to explain why the diver does not appear to be at a depth of 12 m when viewed by an observer outside the pool. (7)

(refractive index of water = 1.33)

This is an example of a labelling system that we would recommend.

A good guide for students to use is to look to the right of the question at the numbers in brackets. The numbers indicate the start of a new part of a question and they tell students the maximum number of marks awarded for it.

(i) Definitions

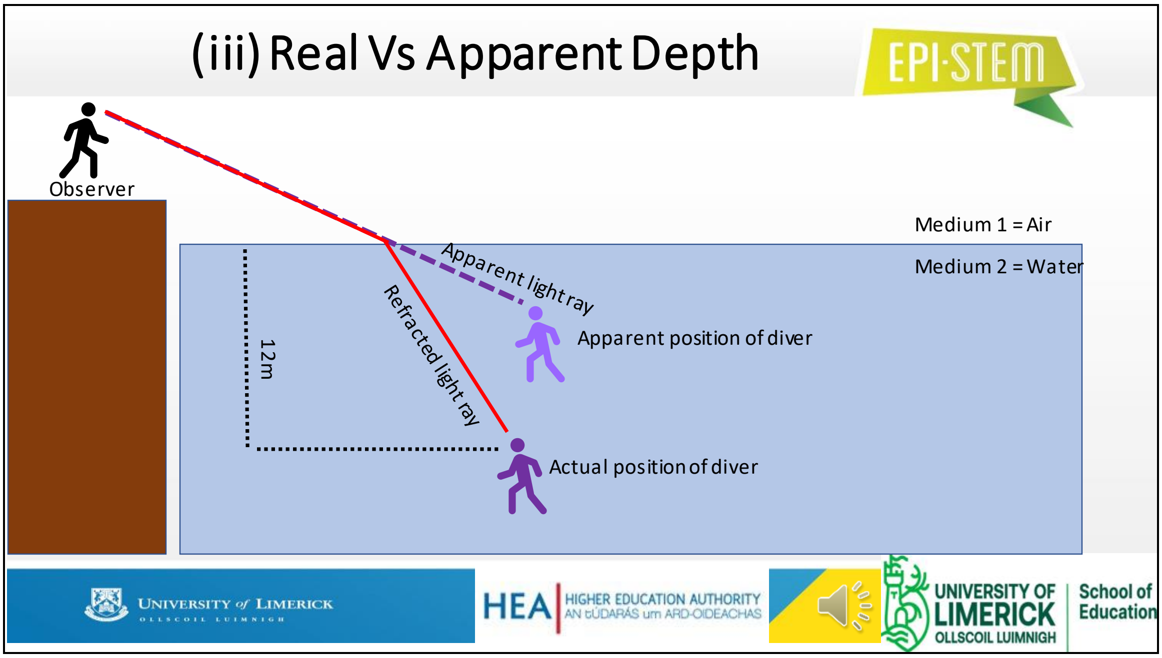
Term	Definition	Marks Awarded
Critical Angle	The angle of incidence corresponds to the angle of refraction of 90°.	2x3
Total Internal Reflection	The angle of incidence is less than the critical angle, resulting in all light being reflected.	3

(ii) Calculate Area of Disc of Light

Step 1 Critical Angle	Step 2 Disc Radius	Step 3 Area of Disc	Step 4 Final Answer
$n = \frac{1}{Sin(C)}$ $1.33 = \frac{1}{Sin(C)}$ $C = Sin^{-1}(\frac{1}{1.33})$ $C = 48.8°$	$Tan(\theta) = \frac{r}{d}$ $Tan(48.8) = \frac{r}{12}$ $(12)Tan(48.8) = r$ r = 13.7m	$A = \pi r^2$ $A = \pi(13.7)^2$	$A = 590m^2$

These are the following steps to answer the question. Each completed step is worth 3 marks.

First the student must calculate the critical angle, then the disc radius, before finally determining the area of the disc. Omission of correct units, will result in the loss of 1 mark.



As shown in the diagram, the observer's eyes wrongly interprets the position of the diver to less deep than they actually are. This is because our brains do not account for refraction. The light ray bends because it is travelling through a second medium of different density.

This question is worth 7 marks. To get the first 4, the refracted ray needs to be drawn, and to get the remaining 3 marks, the apparent ray or position of image needs to be drawn.

Overview of Topics

EPI·STEM

Higher Level

- ✓ Experiment Question
- ✓ Theory Question

Ordinary Level

- ❑ Experiment Question
- ❑ Theory Question

2021 Q3 OL

EPI·STEM

A student carried out an experiment to measure *f*, the focal length of a converging lens.

(*i*) Draw a labelled diagram of the apparatus used in this experiment.

(*ii*) On your diagram, indicate and label the object distance *u* and the image distance *v*. (18)

(*iii*) Name the instrument used to measure the object distance and the image distance.

(*iv*) How did the student know that the correct image distance had been found?

(*v*) State the formula used to calculate *f*.

(*vi*) The student placed an object 16 cm in front of the converging lens. It produced an image at a distance of 48 cm from the lens. Calculate the focal length of this lens.

(*vii*) Why will this experiment not work if the object is placed very close to the lens? (22)

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(i) & (ii) Labelled Diagram

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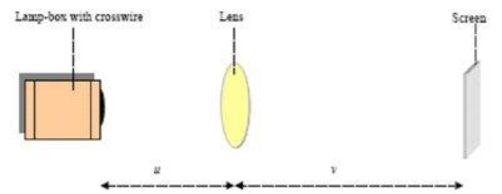

Find a rough value for f.
Measure object distance u and image distance v.
Find f from

Plot 1/u against 1/v. Where the graph cuts the axes gives a value for 1/f.

Precautions
Avoid parallax measuring distances
Make u greater the than the rough valve for f.

(i) 12 marks in total.

Must include:

- Crosswire, ray box (3 marks).
- (Converging) lens (3 marks).
- Screen (3 marks).
- Detail e.g., correct arrangement, optical bench, meter stick, etc. (3 marks).

(ii) 6 marks in total.

Must include:

- Correct position of u and v (6 marks).

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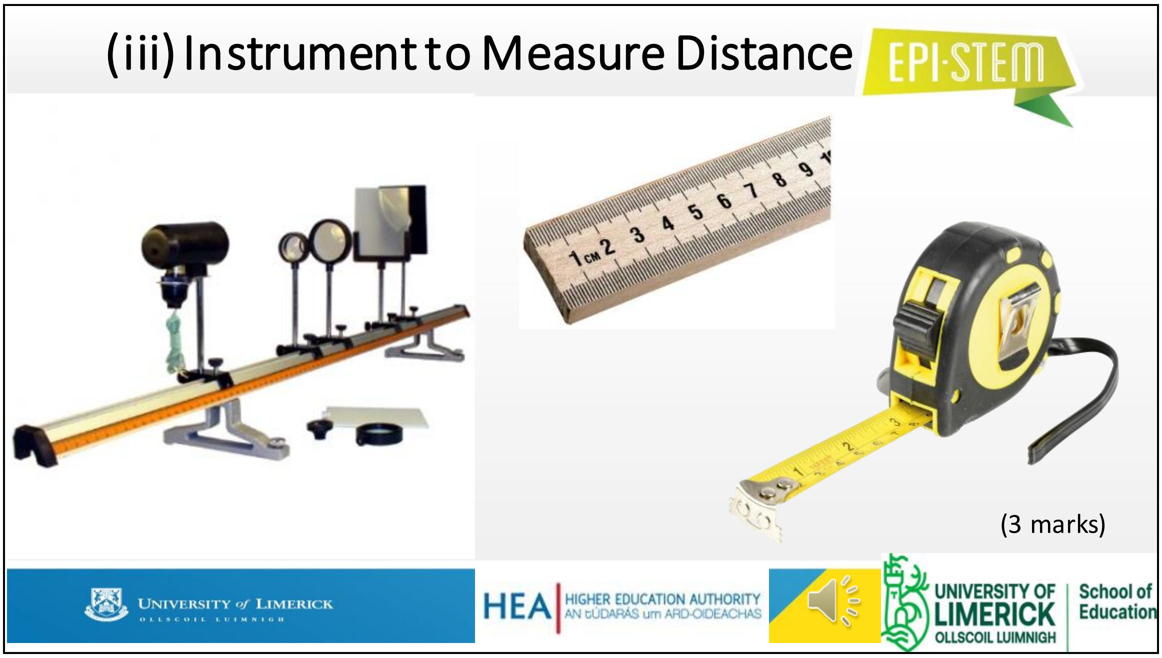
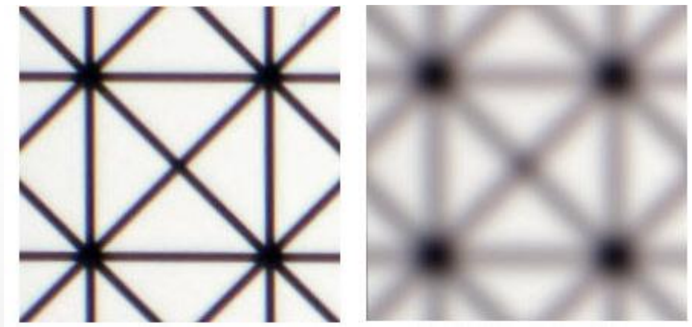
Part 1 and 2 of this question asks the student to draw a labelled diagram.
For a total of 18 marks, students must include:

- A crosswire or ray box
- A lens
- A screen
- An additional detail, such as the correct arrangement, an optical bench, or meter stick
- And the correct positions of u and v distances.



The next part of the question asks students to name any suitable instrument that could be uses to measure the object and image distance in this experiment.
For 3 marks, students could have said a meter stick, measuring tape, optical bench with scale, or ruler.

(iv) Determine when Correct Image Formed



- Image in sharp focus (3 marks).

The question then asks the student how they would know when the correct image distance had been found.
For three marks, students had to state that the image formed was in sharp focus.

(v) Formula to Calculate Focal Length

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$ (6 marks)

$$\frac{1}{focal\ length} = \frac{1}{object\ distance} + \frac{1}{image\ distance}$$

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Part 5 of the question asks students to state the formula used to calculate the focal length. For 6 marks, they needed to answer 1/f = 1/u + 1/v

(vi) Calculate Focal Length

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$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{f} = \frac{1}{16} + \frac{1}{48}$$

$$\frac{1}{f} = \frac{1}{12}$$

$$f = 12cm$$

(6 marks)

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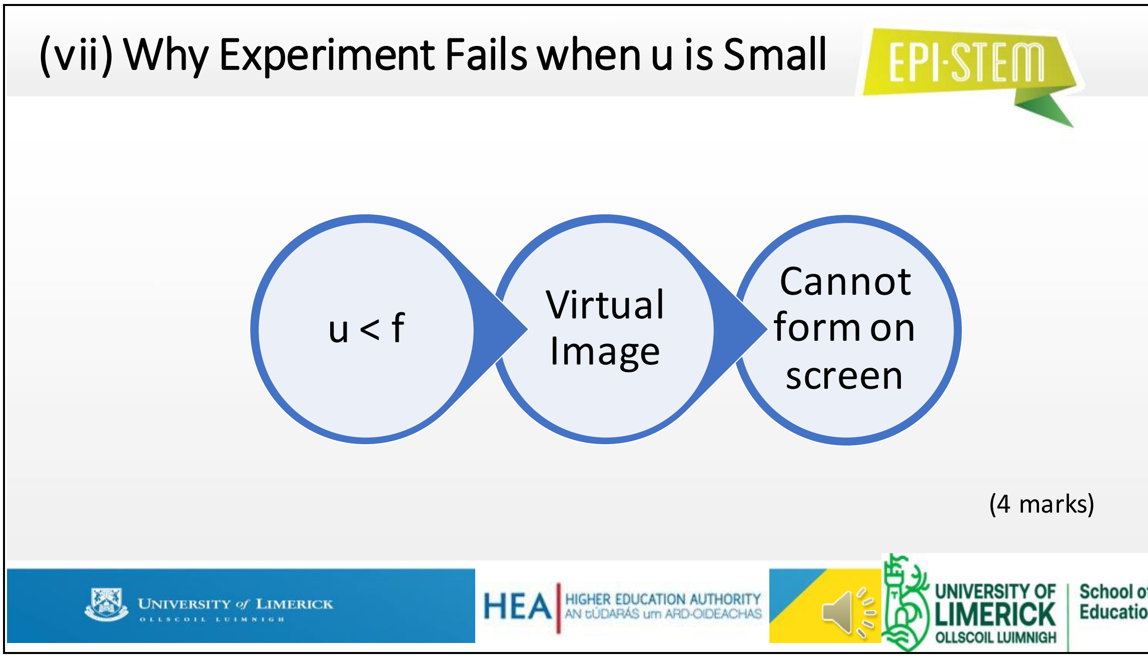
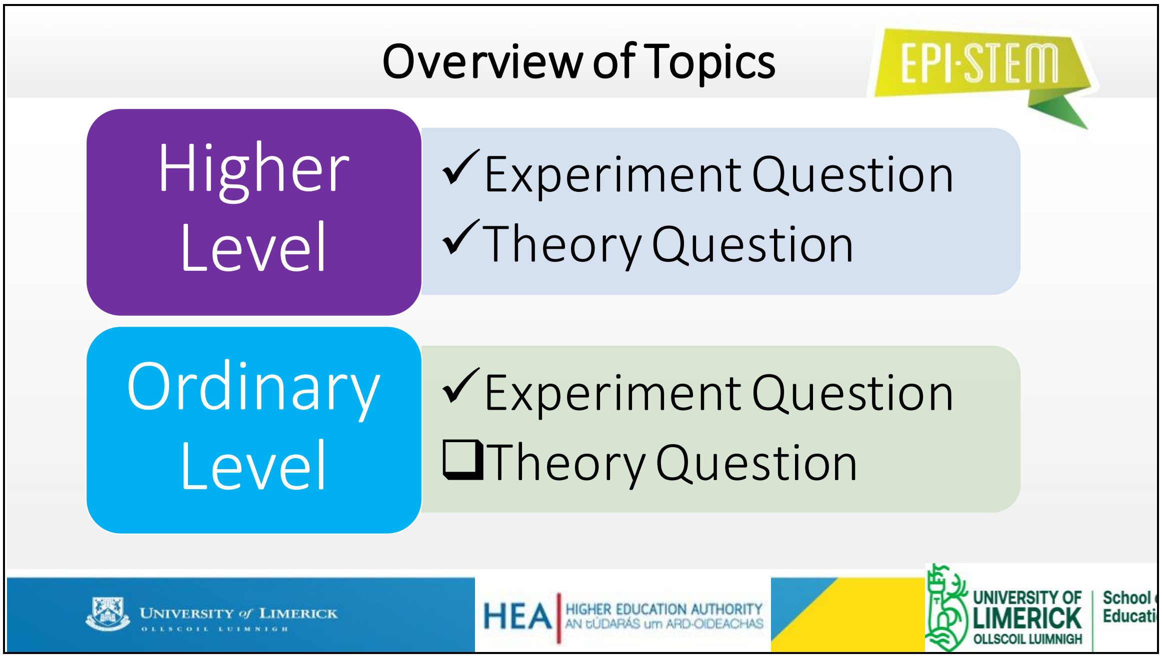
The student is then asked to use this formula to calculate the focal length, when the object and image distances are given. This calculation is worth 6 marks.



Finally, the student is asked to explain why the experiment won't work if the object is placed too close to the lens.
In order to get 4 marks, they need to explain that a virtual image is formed when u is less than f, and we cannot form this image on the screen.


Overview of Topics
EPI·STEM
Higher Level
✓Experiment Question
✓Theory Question
Ordinary Level
✓Experiment Question
❑Theory Question
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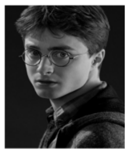
2019 Q11 OL



One of the most common sights anywhere in the world are eyeglasses. Since we depend so much on the lenses inside those frames to improve our view of the world, you might wonder just what goes into creating them.

On the back of your eye is a complex layer of cells known as the retina. When you look at an object, an image is formed on the retina. The retina reacts to light and conveys that information to the brain.

To do all that, the eye has a lens between the retina and the pupil and a transparent covering called the cornea. The pupil allows light to enter the eye. The lens, the ciliary muscles and the cornea work together to focus the image onto the retina. The lens has a different power depending on whether the object being viewed is nearby or far away.

Sometimes the eye doesn't focus quite right. Most vision problems occur when the eye cannot focus the image onto the retina. The most common problems associated with the eye are as follows:

- Myopia (short sightedness) occurs when a distant object looks blurred. Short sightedness is corrected with a diverging lens.
- Hyperopia (long sightedness) occurs when a nearby object looks blurred. Long sightedness is corrected with a converging lens.

Placing the correct type and power of lens in front of the eye compensates for the eye's inability to focus the image on the retina.

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The next ordinary level exam paper question is taken from the 2019 exam, Q11. Before the questions is a short passage. We recommend students take the time to read these during the exam, as in this case more than 60% of the answers could be found within this short paragraph.

2019 Q11 OL

(*a*) Name the part of the eye where an image is formed. (7)

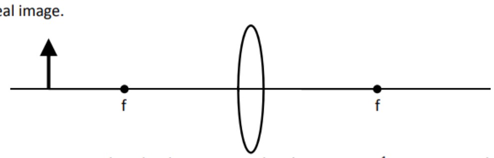
(*b*) What is the function of the pupil? (7)

(*c*) The eye can focus light from both nearby and distant objects. Describe how the eye changes to allow this to happen. (7)

(*d*) Name the two most common eye defects. (7)

(*e*) What type of lens corrects short sightedness? Draw a sketch of this lens. (7)

(*f*) Copy the diagram below into your answerbook and complete the ray diagram to form a real image. (7)

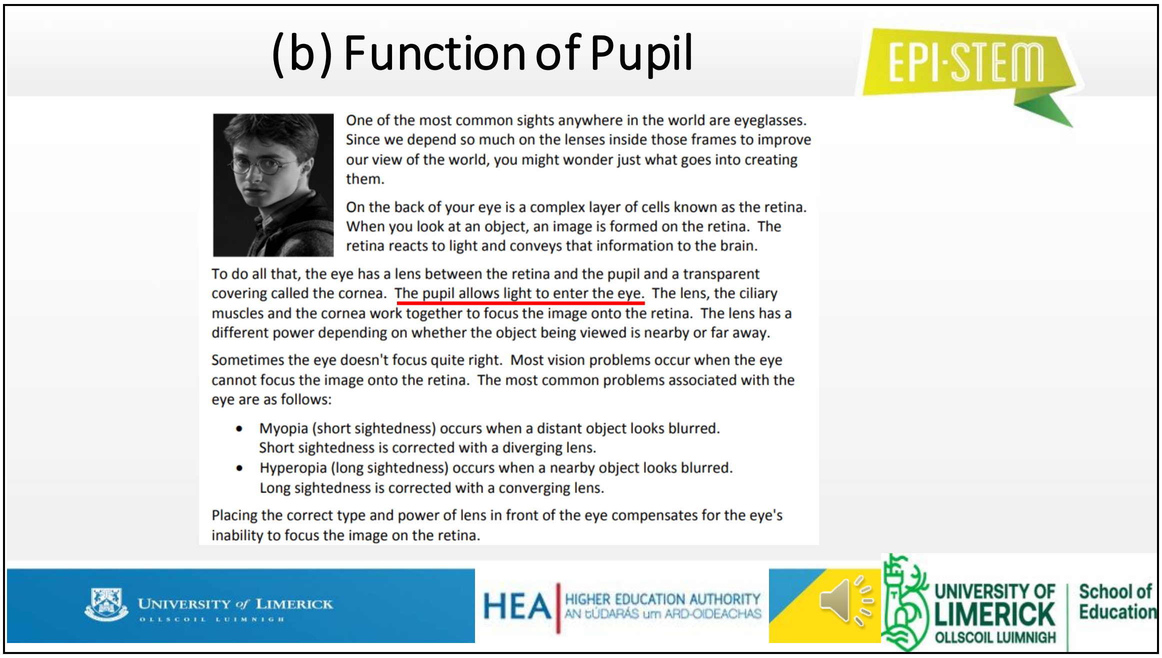


(*g*) The power required to clearly view a nearby object is 38 m^{-1}. A person with an eye defect has a maximum power of 32 m^{-1}. Calculate the power of the lens required to correct this defect? What is the focal length of this lens? (7)

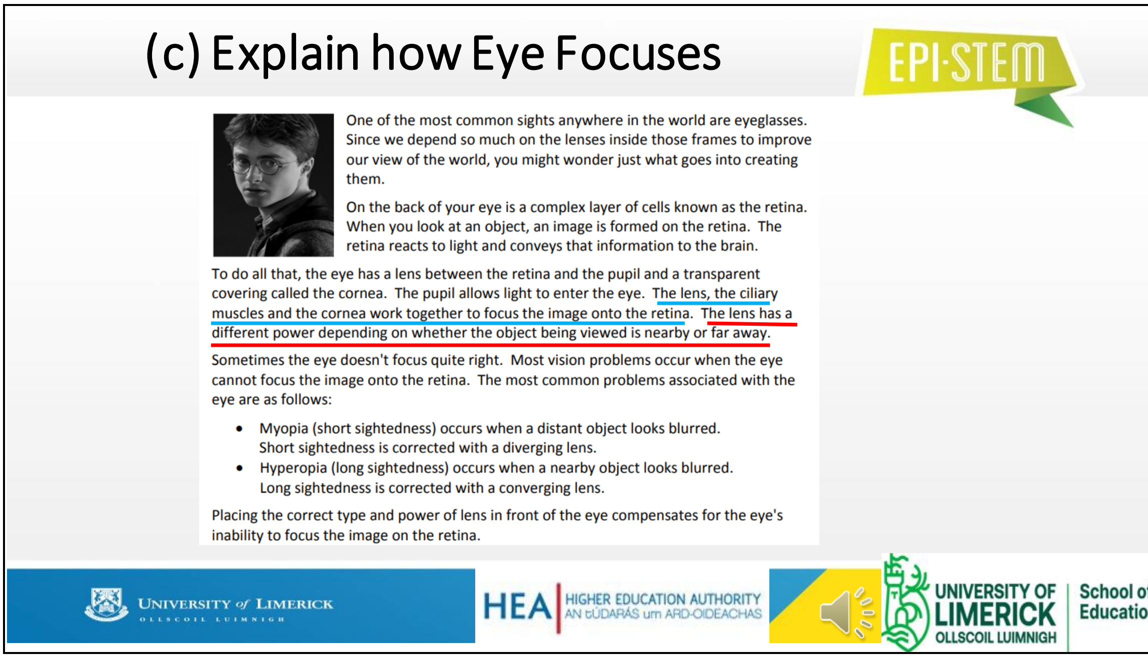
(*h*) Light undergoes refraction as it passes through a lens. What is meant by refraction? (7)

Each part of this question is worth 7 marks.

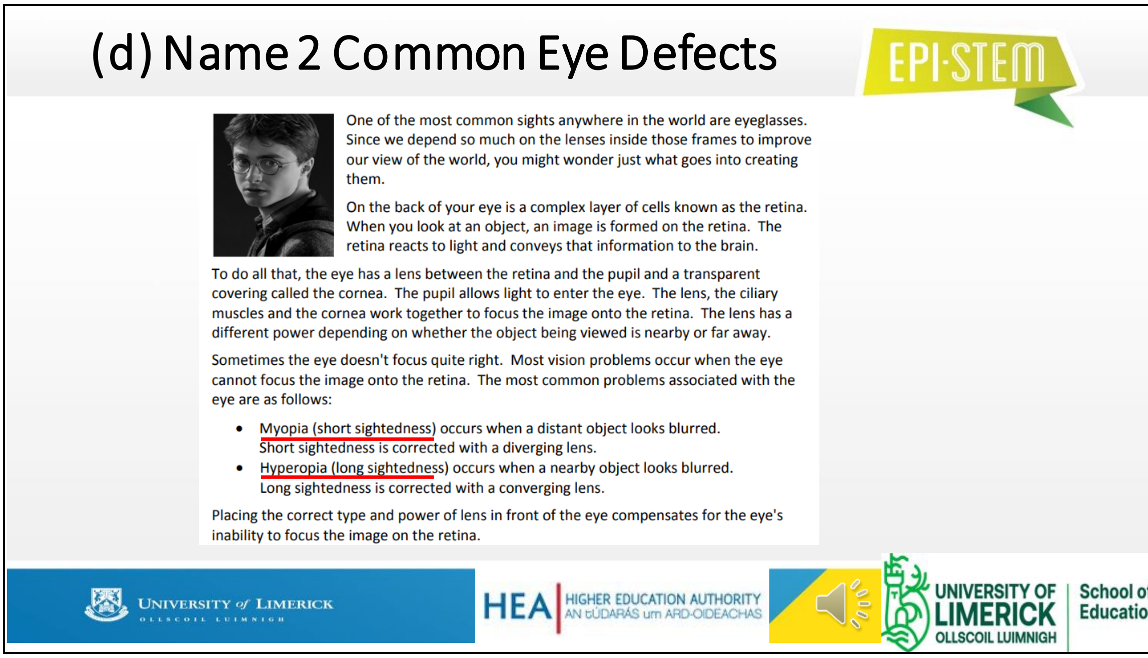
Firstly, students are asked to name the part of the eye that the image is formed at. For 7 marks, students just had to name the retina, or if they just said the back of the eye, then they would have been awarded 4 marks,



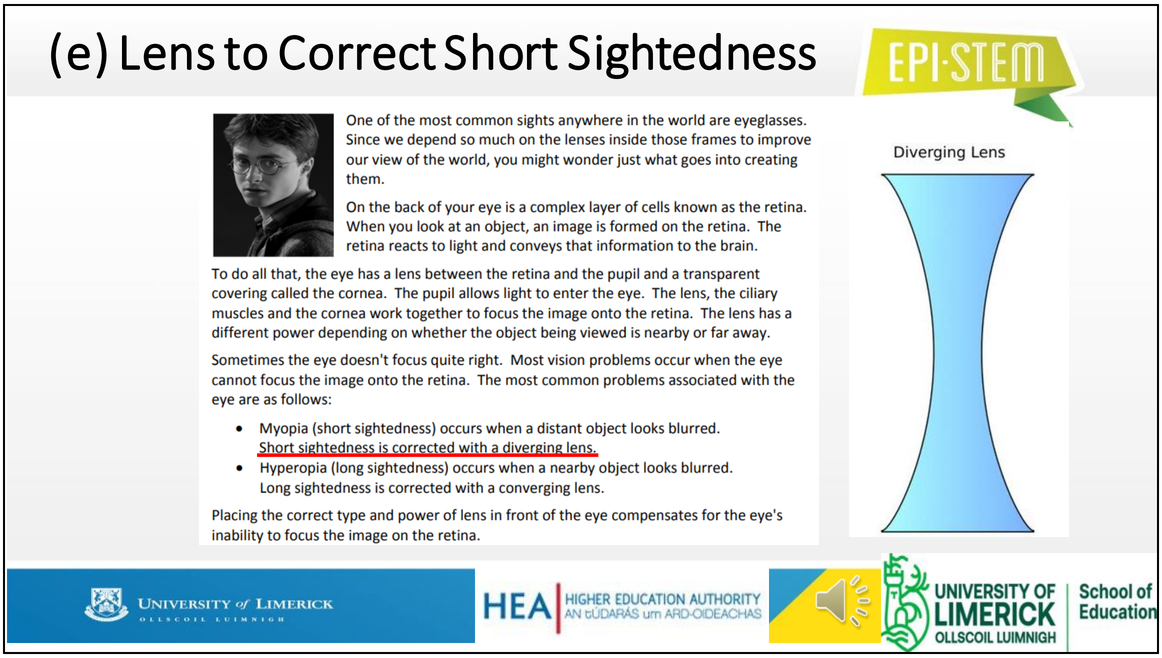
Next students needed to answer that the function of the pupil was to allow light to enter the eye.



Students were told that the eye can focus light from both nearby and faraway objects and were asked to explain how it was able to do this.
Students needed to explain that the lens has different powers or it is able to change shape in order to be awarded 7 marks.
They would have achieved 4 marks if they said that the lens, the ciliary muscles and the cornea work together to focus the image onto the retina

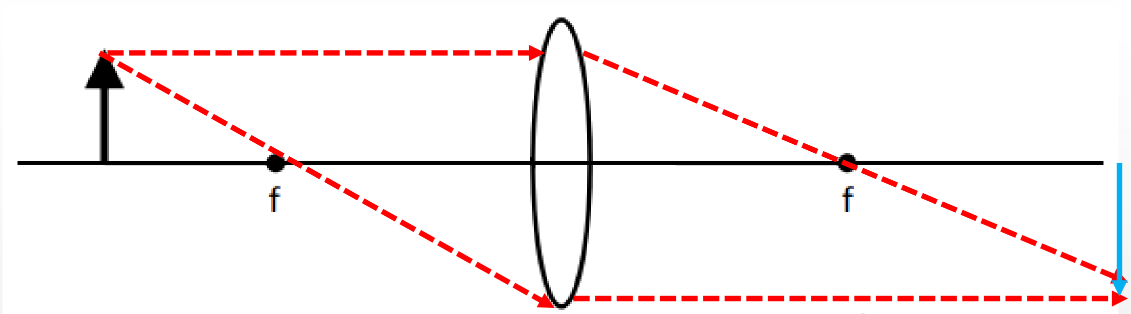


The next part of the question asked for the name of 2 of the most common eye defects.
Myopia is short sightedness and
Hyperopia is long sightedness.



The student is then asked to name and draw a diverging or concave lens as the appropriate lens used to correct short sightedness.

(f) Diagram to Form a Real Image



Part f of the question asks students to copy the diagram and fill in the ray lines that form a real image. The dotted red lines are the light rays and the blue arrow shows the real image formed as a result.

(g) Calculations

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Power of Lens	Focal Length of Lens
$P = 38 - 32$ $P = 6m^{-1}$	$f = \frac{1}{P}$ $f = \frac{1}{6}$ $f = 16.7cm$

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Part g of the question asks the student to calculate the power of the lens needed to correct the defect of a person's eye to allow them to see a sharp image and to calculate the focal length of this lens.
This can be done by using these formulae.

(h) Define Refraction

Term	Definition	Marks Awarded
Refraction	The bending of light when it travels from one medium to another.	7

Finally, the student is asked to define refraction as the bending of light when it travels from one medium to another.

Overview of Topics

EPI·STEM

Higher Level
- ✓ Experiment Question
- ✓ Theory Question

Ordinary Level
- ✓ Experiment Question
- ✓ Theory Question

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Contact Details

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EPI•STEM project: Resources
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This on-line CPD project [HEA funded] is an initiative with EPI•STEM for science and mathematics secondary teachers in Ireland. The research-led development team include:

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