**Physics: 4. Light**

***Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier***

**Something to think about**

“Twinkle twinkle little star . . .”

Why do stars twinkle but not planets?

**Syllabus**

**OP33** Recall that light is a form of energy and that it can be converted into other forms of energy

**OP34**  Show that light travels in straight lines and explain how shadows are formed.

**OP35**  Contrast luminous objects, which are themselves a source of light, with non-luminous objects, which are seen because light is reflected from them.

**OP36**  Recall that white light is made up of different colours which can be separated by dispersion.

**OP37**  Produce a spectrum of white light using appropriate apparatus, and list the colours of the spectrum.

**OP38**  Investigate the reflection of light by plane mirrors, and illustrate this using ray diagrams.

 Demonstrate and explain the operation of a simple periscope.

**OP39** (all higher level)

 Show the refraction of light as it passes from: air to glass, air to water, glass to air, water to air.

 Show refraction of light through a lens.

 Demonstrate the operation of a magnifying glass.

**Questions to make you think**

1. Why does shoe polish (a yucky mucky substance) make your shoes shiny?
2. Can you think of a way to find out if any two people ‘see’ the same colour when they look at the same image?
It’s not as easy as you think!

**Student** **Notes**

**Light is a form of energy and it can be converted to other forms**

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To show that light is a form of energy you must be able to show that it can do work (because energy is the ability to do work).

Work is done when an object is being moved. So we need to show that light can move something.

**Demonstration**

Us a solar panel connected to a motor; when light shines on the solar panel the light energy gets converted to electrical energy and this then gets converted to kinetic energy in the motor (which turns).



**Light travels in straight lines**

**Demonstration**

Notice that you can only see light from the lamp when the holes in the card are lined up (use a piece of cord to line them up).



**How shadows are formed**

Shadows are formed when light coming from a source is blocked.

The shadow is then similar in outline to the object blocking the light.

**Demonstration**

Place your fingers between a candle and a screen and notice that as you bring your finger closer to the candle more light gets blocked out and the shadow gets bigger.

**Reflection is the bouncing of light from a surface**

We can see objects because some of the light which leaves the objects hits our eyes.

**Luminous objects are a source of light while non-luminous objects are seen as a result of light reflected from them.**

Examples of luminous objects: the sun, a light-bulb, a candle.

Examples of non-luminous objects: everything else (not emitting their own light)

**To investigate the reflection of light by plane mirrors**

**Demonstration**

Use a ray box to shine a ray of light off a mirror.

Notice that it reflects back out at the same angle as it goes in.

Complete the diagram on the right.



**How a periscope works**

1. Some of the light coming from the card hits the first mirror.
2. It then gets reflected from this onto the second mirror.
3. It next gets reflected off of this second mirror and travels out to the eye of the student..

**Refraction**

**Refraction is the bending of light as it passes from one medium to another**

**To demonstrate refraction**

Shine a ray of light into a glass block and notice that it bends on the way in and also on the way out.

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**Show refraction of light through a lens**

A lens is a curved piece of glass used to bend (refract) light inwards or outwards.



**To demonstrate the operation of a magnifying glass**

A magnifying glass refracts light to give a magnified image of the object.

**Applications of refraction**

You only need to know a couple of these:

Lenses, spectacles, magnifying glass, microscope, binoculars, telescopes, camera lenses, prisms, projectors, endoscope, periscope etc.

**Dispersion**

White light is made up of different colours which can be separated by dispersion

**Dispersion is the breaking up of white light into its individual colours (called a spectrum)**

**The colours of the spectrum are Red, Orange, Yellow, Green, Blue, Indigo and Violet.**

Make up a mnemonic to help yourself remember them e.g. **R**ichard **O**f **Y**ork **G**ave **B**attle **I**n **V**ain?



**To produce a spectrum of white light**

Use a light bulb, a prism and a screen.

Turn the prism slowly until a spectrum is formed on the screen.

**Note that red gets bent the least and violet gets bent the most.**

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**Exam questions**

**Reflection**

1. [2006 OL][2010 OL][2012 OL]

An experiment on light was set up as shown.

Answer the questions that follow.

1. What would a person see if the three cards were set up as shown?
2. What would a person see if the middle card was moved sideways?
3. What does this experiment tell us about light?
4. [2007 OL]

Describe, with the help of a labelled diagram, how you could carry out an experiment to show that light travels in straight lines.

Use the following headings: Equipment: Result: Labelled diagram

1. [2008 OL] [2010 OL]

The diagram shows a ray of light striking a plane mirror.

1. Complete the path taken by the ray in the diagram.
2. Name the property of light shown.
3. Name an instrument that is based on the use of reflection of light from mirrors.
4. [2007 OL] [2010]

The diagram shows a ray of light shining onto a plane mirror in a periscope.

1. Complete the path taken by the ray in the diagram.
2. Give one use for a periscope.



1. [2011 OL]

The diagram shows a ray of light striking a plane mirror

1. Complete the diagram to show what happens to the ray when it strikes the mirror.
2. What word describes this?

A student set up the equipment shown in the diagram in an investigation on the use of mirrors.

Answer the questions below about this investigation.

1. Name the piece of equipment the student has constructed.
2. What happens to the light rays when they shine on mirror A?
3. Give one use for the device made by the student.
4. [2006]

A pupil made a *simple periscope* using two plane (flat) mirrors.

The mirrors were arranged as shown in the diagram.

The pupil looked through the periscope at the word ‘Science’ written on a card pinned to the laboratory wall.

1. Did the pupil see first image or the second image when she looked through the periscope?
2. Give a *reason* for your answer.



1. [2006]

Why is the word Ambulance painted in reverse on the front of many ambulances?

1. [2008]

The photograph shows a wader i.e. a bird that feeds in shallow water.

1. Is the image of the bird produced by reflection or by refraction?
2. Give a reason for your answer.

**Refraction**



1. [2006][2007]

What is refraction of light?

1. [2012]

What causes the appearance of a ‘second’ drinking straw in the drink in the glass shown in the photograph?

1. [2007] [2008]

Give an application of this bending of light.

1. [2007]

Name another way in which the direction of a light ray can be changed apart from refraction.

1. [2007]

A glass block like the one shown in the diagram was used in an experiment in which a narrow beam (ray) of light was shone through it. The light passed from air to glass, on entry, and glass to air, on exit.

The path of this light ray is shown in the second diagram.

The light ray from A bends both on entering and on leaving the glass block.

Pick, from ‘*rays*’ P, Q, R or S the path taken by the light ray leaving the glass.

1. [2011]

A narrow beam (ray) of white light is directed onto a triangular glass prism as shown in the diagram.

The paths of four rays: R1, R2, R3 and R4 produced from this ray of white light are shown in the diagram.

1. What word is used to describe the deflection of ray one (R1)?
2. Rays two, three and four (R2, R3 and R4) enter and leave the prism and change direction each time.

What is this change of direction of light called?

1. A single ray of white light enters the prism and a band of light of many colours leaves the prism.

Just three of the emergent rays are shown in the diagram.

The coloured rays are produced from the white light.

What is this separation of white light into coloured light called?

1. Give the colour of light that can be seen at the extreme ends A and B on the white screen.
2. Name a natural phenomenon that produces a band of coloured light from sunlight.
3. [2010]

The diagram shows three narrow beams of light (rays) hitting a lens.

Draw one ray that passes through the lens without refraction and one ray that is refracted by the lens in the diagram.

**Dispersion**



1. [2010 OL] [2008 OL][2012 OL]

The equipment shown in the diagram was set up and used in an experiment on light.

The light passes through A to form a band of colours.

1. Name the piece of equipment labelled A.
2. Name the colour labelled B.
3. [2008]

The diagram shows a ray of white light entering a triangular glass prism.

The light passes through the prism and emerges as a band of coloured light.

1. What does this experiment show about the composition of white light?
2. What is this separation of white light into different colours called?
3. What name is given to the band of coloured light produced?
4. State the *colour of the light labelled* X and the *colour of the light labelled* Y at the extreme ends of the band of light illustrated in the diagram.
5. [2010][2008 OL] [2007]

Thunder and lightning occur during electric storms.

1. Which is detected first, the flash of lightning or the clap of thunder?
2. What does this tell us about the speed of light?

**Exam Solutions**

1. The lamp on the other side.
2. Nothing / card / no light
3. Light travels in straight lines
4. Equipment: Three pieces of card with holes in centre

Procedure: Set up cards with holes in straight line

Place lit lamp at one end / look through to lamp at other end

Result: Light travels straight through / light can be seen / move the card and light cannot be seen

1. The reflected ray should be going out at the same angle as the light ray is going in.
2. Reflection
3. A periscope
4. The ray goes down and then out.
5. To see over objects/ see around corners/ submarine…
6. Light ray coming back off mirror at the same angle on the other side
7. Reflection
8. Periscope
9. Down the tube (second mirror / B) (stated or shown)
10. Look over (around) objects / submarines
11. The pupil would see the first image.
12. Because the word was reflected twice.
13. Because mirrors invert the image therefore when drivers look in their mirrors they see the word ‘Ambulance’ as it would normally appear.
14. Reflection
15. The water surface acts like a mirror
16. Refraction is the bending of light as it passes from one medium to another.
17. Refraction
18. Lenses/ spectacles/ magnifying glass/ microscope/ binoculars/ telescopes/ camera lenses/ prisms/ projectors/ endoscope/ periscope/…
19. Reflection
20. R
21. Reflection
22. Refraction
23. Dispersion
24. A red, B violet
25. Rainbow
26. See diagram
27. A: Prism, B: Green
28. White light is made up of different colours.
29. Dispersion
30. A spectrum
31. X is red , Y is violet/ purple
32. The flash of lightning
33. Light travels faster than sound

**General Questions**

1. Describe briefly how you would show the conversion of light energy to electrical energy to kinetic energy.
2. Draw a diagram and write a brief note to demonstrate that light is a form of energy.
3. What is meant by the reflection of light?
4. What is meant by a luminous object?
5. Give an example of a luminous object.
6. Give two observations that suggest that light travels in straight lines.
7. Explain, using a diagram, how a shadow of a person is formed on a sunny day.
8. What is the name given to the change in direction of light as it enters a prism?
9. Describe, with the aid of a diagram, an experiment to show the refraction of light as it passes through a lens.
10. Draw diagrams to show how(i) a Concave Lens, and (ii) a Convex Lens works

**Higher Order Questions**

1. Why do rainbows often appear after a heavy shower of rain?
2. Did you know: the only part of your body that you can kiss in the mirror is your mouth?

**Teaching *Light***

**Syllabus**

**OP33** Understand that light is a form of energy and that it can be converted to other forms

**OP34** Show that light travels in straight lines and explain how shadows are formed.

**OP35** Understand that luminous objects are a source of light while non-luminous objects are seen as a result of light reflected from them.

**OP36** Recall that white light is made up of different colours which can be separated by dispersion.

**OP37** Produce a spectrum of white light using appropriate apparatus, and list the colours of the spectrum.

**OP38** Investigate the reflection of light by plane mirrors, and illustrate this using ray diagrams.

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**OP39:** (all higher level)

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**OP33: Understand that light is a form of energy and that it can be converted to other forms**

Solar panels are available in the *Energy Conversions* resource box.

To demonstrate that light is a form of energy we must first make sure we know how to recognise that something has energy. A simple approach is to say that if an object has energy it can cause movement, so it’s not enough to have solar panels - they must be connected to something which moves, e.g. a motor.

**OP34: Show that light travels in straight lines and explain how shadows are formed.**

* **To show that light travels in straight lines**

The apparatus is available in the *Light Resources* Box.

You don’t need to use a candle - any object will do.

Alternatively sprinkle some power (e.g. chalk dust or talcum powder) over a laser beam to make it visible.

* **To investigate how shadows are formed**

Use the ray-box as the light source or alternatively just use a candle.

It’s worthwhile asking the students to predict the outcome of the activity in advance.

**OP35: Understand that luminous objects are a source of light while non-luminous objects are seen as a result of light reflected from them.**

**OP36: Recall that white light is made up of different colours which can be separated by dispersion.**

**OP37: Produce a spectrum of white light using appropriate apparatus, and list the colours of the spectrum.**

* **Produce a spectrum of white light using appropriate apparatus**

The apparatus is available in the ray-boxes kit.

It can be tricky to generate a clear spectrum, but students generally get there with time. They certainly enjoy the activity. It’s possible to create a large spectrum on the ceiling using an overhead projector as the light source, but it takes practice.

* **List the colours of the spectrum**

DO NOT UNDER ANY CIRCUMSTANCES tell the students what the seven colours are without first giving them the chance to identify them for themselves; it’s great fun trying to spot them.

We give the impression that these seven colours are objective (they really exist, regardless of the observer) but in fact they are quite subjective and what an observer sees depends upon not only the colours that ‘are there’ but also physiological factors (and even cultural ones).

Newton himself first came up with the notion of seven colours partly because he believed that seven was a special number (e.g. seven different notes in a musical scale, seven days in the week).

The colours of the rainbow can be remembered using the memonic ***R****ichard* ***O****f* ***Y****ork* ***G****ave* ***B****attle* ***I****n* ***V****ain* (ROY G. BIV is another one), but you have to admit they’re a bit stupid and I’m sure students can come up with something better themselves.

**OP38: Investigate the reflection of light by plane mirrors, and illustrate this using ray diagrams; demonstrate and explain the operation of a simple periscope.**

* **Investigate the reflection of light by plane mirrors, and illustrate this using ray diagrams.**

All apparatus is available in the Ray Boxes and the *Light Resources* Box.

Students generally aren’t familiar with using protractors in first-year so a ‘qualitative analysis’ should do fine (“the angle in equals the reflected angle”). Text-books refer to the angle of incidence as being the angle between the incident ray and the normal, but for me at this level that just complicates things, so until I’m told otherwise I will continue to use the more straightforward angle between the ray and the block itself.

* **Demonstrate and explain the operation of a simple periscope.**

The apparatus is available in the Ray Boxes and the *Light Resources* Box.

There are enough mirrors to make a class set of periscopes using retort stands. Remind students that the object of the exercise is view something which they could not otherwise see because of an obstacle in the way.

So they have to set up the apparatus below bench level and if it works correctly they should be able to view something above the desk while their head is still below bench-level.

First to build it successfully gets a prize.

For homework they can take home two mirrors and try to make a permanent periscope. You can keep any really good ones and store them in the resources box.

Remind students that these were very important resources in the trenches during World War One.

**OP39: (all higher level): Show the refraction of light as it passes from: air to glass, air to water, glass to air, water to air****; show refraction of light through a lens; demonstrate the operation of a magnifying glass.**

* **Show the refraction of light as it passes from: air to glass, air to water, glass to air, water to air**

Demonstrating the refraction of light as it passes from air to glass and glass to air; this is straightforward using the glass blocks available in the ray-boxes kits.

Demonstrating the refraction of light as it passes from air to water and water to air; I’m not sure what they want us to do here.

One option is to use a container of water, for example in a petri-dish, similar to what we do for the glass block (and conveniently ignore that the light actually passed from *air to plastic and then to water* on the way in, and the opposite on the way out).

Another possibility is that they just want us to dip a pencil into a beaker of water and notice that it bends (again ignoring the glass interface).

I suppose to be safe we should cover both and then prepare ourselves for the exam paper which asks for something else entirely.

* **Show refraction of light through a lens.**

Converging and diverging lenses are available in the ray-box kits.

* **Demonstrate the operation of a magnifying glass.**

You need to buy a class set of flat convex (converging) lenses to demonstrate this. Hold the lens over some text and notice that the image is magnified.

**Activities**

1. If it’s a sunny day bring the troops outside and let them try to ignite tissue paper using lenses by placing the paper at the focal point (they will find this by trial and error).
2. Get students to form images of distant objects on a screen (a white page) using the lenses.

This is always impressive, particularly when they notice that the image is in colour and upside down.