Wave Behaviour of Light
Topic 3.1

Teacher's Notes

Introduction

The topic of light has two important components. One is the properties that have led to both our discovery of atomic and subatomic particles and the other is the way that it behaves allowing for "vision" and understanding of our universe.

Practicals

Summative

There are two possible summative practicals that can be conducted with this unit.

- One is the measurement of black holes through calculations based on gravity waves.
- The other is the detection of methane emissions through satellite imagery

Both are based on current areas of physics research and development, both Space based.

Formative

There are a number of activities detailed in this plan

- Polaroid glasses
- Measuring the CMB
- Double slit wavelength measurement

Lesson preparation

A note of caution: it is recommended that you keep to transverse waves for this topic. Discussion of other wave types can cause confusion, especially when you discuss the 3-dimensional nation of light (electric field / magnetic field / direction of movement).

Prior knowledge

- Electric charge, electric fields
- Magnetic fields
- Transverse waves
- Basic atomic shell structure (year 10 level)

Lesson support props

- Fish tank or other simple, see-through water container that allows you to make small waves
- Compass

Lesson delivery

This covers the entire topic, which will be delivered over a number of lessons. At the beginning of each lesson, make sure you refresh the previous lesson.

Transverse waves

- Have students picture **non-breaking** waves (talk about local bays, etc.)
- Possible opening video: GCSE Physics – Intro to Waves
    - You may consider following with their Reflection and Refraction videos (don't video overload)

Diffraction

- This can be covered using classical physics and the concept of each point creating a new wave front, or by using the quantum description. Base your decision on your cohort, but consider that most students will enjoy that they are being taught "quantum".

The wave equation

This is an area where students can be extended; the wave equation only works at one point on a wave at one point in time because waves change. Options include:

- Talk about dispersion, how ocean waves are formed by the transfer of wind energy to the sea through capillary waves (emphasise how small they are), and yet, the waves that get to the beach from far away are very long waves. Have the students consider how entropy has "converted" the motion from one of small but fast movements to large, slow movements.
- Talk about gravitational red-shift or red-shift due to the expanding universe has altered the frequency/wavelength of light as it travelled toward Earth.

Light

Consider how you will refer to "light"

- the visible spectrum only or
- all of the EM spectrum with visible and invisible ranges

I prefer (and these resources are based on) calling the entire EM spectrum light. This is so that students understand that a red light only differs from the Wi-Fi signal due to its wavelength/frequency.

Develop the concept of light as an EM wave slowly:

- Introduce universal electric and magnetic fields by discussing gravity
    - Can't see it
    - Can't measure it
    - Can see its effects
    - Can measure it by measuring its effects
    - Its everywhere through the universe
    - Same with a magnetic field; can't see it, but consider a compass
- Revise the concept of charge and electric fields
- Revise how a moving charge in a wire creates a magnetic field
- Reinforce: changing electric field produces changing magnetic field produces changing electric field produces changing magnetic field produces ……
- Link to how moving an electron will
    - Create a moving electric field
    - Which will create a moving magnetic field
    - Both of which are movements in the universal fields that will travel from the point of creation
    - Thus, you have created light (very low frequency, very long light)

You may wish to use the GCSE Physics Electromagnetic Waves video here to consolidate

Antennas

Note: there have been antenna questions in the external exam on a number of occasions so ensure this aspect is well understood.

Research activities

- Have students look at antenna design, consider length, type of wire, etc. Answer the question, why long-distance radios use stretched out, long wires for transmission/reception.
- A long copper wire can be used to "listen" to the cosmic microwave background.
    - Set up a long copper wire between two retort stands
    - Make sure it is well insulated and away from any 240V or other transmission lines

    - Connect an oscilloscope to it and look for 2mm wavelength (160GHz) signal.
    - You can also "look" for 240V signals, simply by looking for 50Hz signals.
    - Cosmic Microwave Background Explained (PBS Space Time)

Photon emission and absorption by atoms

Colours, what you see

This is a great area to stretch student's thinking

- You only "see" RGB
- But you can "see" the visible spectrum. How?
- What do your eyes see (frequency, intensity)?
- What does your brain do?
- How do TVs give you "better" colours?
- What is the maximum colour resolution you can see?
- What is the resolution on your phone?

Checking comprehension

Key terminology

- Transverse wave
- Reflection, Refraction, Diffraction
- Scattering as a type of reflection
- Polarisation, Plane of polarisation
- Monochromatic

Mathematical activities

- Using wave equation (including changing subject)

Conclusion

Student’s knowledge of light should be comprehensive at this point.

They should be adept at mathematical questions using

- The wave equation
- The double slit equation
- The diffraction grating equation