Teaching ideas for Option G, *Electromagnetic waves*

Questions

A number of worksheets are provided for this Option:

- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

Teaching ideas

- A common exam question concerns the blue colour of a clear sky. This is usually explained in terms of Rayleigh scattering of light, where the scattered intensity is $I \propto \frac{1}{\lambda^4}$ and so blue light, having the smallest wavelength, scatters the most. However, violet has an even smaller wavelength so why doesn't the sky look violet instead? This is a reasonable question that has been asked many times by bright students! The answer is not particularly simple and appears to have to do with the fact that the cone cells in the eye are, in general, not particularly sensitive to violet. Furthermore, the presence of violet scattered light excites not just the blue cones cells but also the red and green cone cells to a small extent (see page 84 of the Exam preparation guide for the graph showing the sensitivity of cone cells as a function of wavelength). This means that the result of the combination of these colours will make the sky look bluish rather than violet.
- Subject reports, year after year, make it clear that students come to the exam very badly prepared to answer questions about ray diagrams. It is therefore important that as many ray diagram examples as possible are done in class. A number of support and extended worksheets address this issue.
- A question often asked by students is what happens to the energy of the waves at a point where destructive interference takes place. The answer has to be that the energy is redistributed along the line of observation with zero intensity at the exact point of destructive interference and four times as much intensity, as that from a single source, at the exact point of constructive interference.
- The simulation at http://www.compadre.org/OSP/document/ServeFile.cfm?ID=8257&DocID=886 shows how the focal length of a lens changes as the radii of curvature of its sides change, as the thickness of the lens changes and as the refractive indices of the material of the lens and of the media surrounding the lens change. Very instructive.
- Diffraction by a single slit or many slits for various wavelengths, slits widths and slit separations may be demonstrated in the classroom with a very nice simulation at: http://www.compadre.org/osp/items/detail.cfm?ID=8331
- Thin film interference may be demonstrated with http://www.compadre.org/osp/items/detail.cfm?ID=9990 where you can change refractive indices for the top, film and bottom medium. You can also change film thickness and choose the wavelength you want to concentrate on.
- It is important that students understand when a phase change occurs in thin film interference. The example of a single pulse reflecting from (1) a fixed end and (2) a free end may help in understanding.

Practical activities/ICT

- Try the following site for a wide variety of simulations in optics, diffraction and interference: http://www.compadre.org/osp/search/search.cfm?gs=228&b=1&qc=Compiled%20Simulation
- A straightforward short video on spherical aberration is at: http://www.youtube.com/watch?v=E85FZ7WLvao&feature=related . The video shows the effect of 'stopping'.
- Similarly, see http://www.youtube.com/watch?v=yOR4WHgRfvI&feature=related for chromatic aberration. Making the rays paraxial (which solves the problem for spherical aberration) does not solve the problem here.

Common problems

- As mentioned earlier, ray diagrams are a perennial problem – which can only be solved if students are exposed to very many situations where they have to draw such diagrams.
- Thin film interference is also a source of confusion for students who usually find it difficult to explain the origin of colour in thin film interference as well as the origin of the interference itself.

Theory of knowledge (TOK)

- X-Ray diffraction played a crucial role in the discovery of DNA and its structure. A technique that was originally designed for use in physics found a great application in biochemistry.
- A very amusing story, but also one with connections to TOK and how science progresses, is the following:
  In the 1800s, Augustine Jean Fresnel was one of the main proponents of the electromagnetic theory of light as the basis on which diffraction phenomena could be understood. In 1818 he entered a competition of the French Academy and actually won the first prize with a paper on diffraction. The committee of judges consisted of the elite of French physics and included among others the mathematical physicist Simeon Poisson. Poisson used Fresnel's theory to deduce that a beam of light directed towards a spherical object would diffract in such a way that, at some distance behind the ball, a bright spot of light would appear. This was as the result of diffraction. This conclusion appeared so absurd to Poisson that he considered it to be a sign that Fresnel's theory had to be wrong. However, the existence of this spot of light was verified experimentally almost immediately by Dominique Arago! The argument that was supposed to kill a theory became one of its amazing supporters and the spot of light that was not supposed to exist is now called Poisson's spot, i.e. by the name of the man who thought it impossible.
  You can read more about this interesting story at many places, including http://io9.com/5707749/poissons-spot--the-greatest-burn-in-physics