L2 Foundation of Physics 2B Optics 2019-20

O.1 Summary

Learning outcome: To introduce the **harmonic wave solution** of **Maxwell's wave equation**, and associated concepts: **monochromatic light**, **wave vector**, **intensity**, **polarization**, **scalar approximation**.

In Optics f2f: Sections 1.3 to 1.6, 1.8, 1.11, 1.12

Key equations: The harmonic wave solution is

$$\underline{E} = \underline{E}_0 \cos(\underline{k} \cdot \underline{r} - \omega t) \ , \tag{1}$$

where $\underline{k}$ the **wave vector**. Its direction determines the direction of propagation and it has a magnitude

$$k = \frac{2\pi}{\lambda} \ , \tag{2}$$

where λ is the wavelength. If $\underline{E}_0$ is time independent then the harmonic wave describes monochromatic light. For $\lambda = 600$ nm, the field changes sign every femtosecond!

The magnitude of $\underline{E}_0$ determines the amplitude of the field. In optics, we measure the **intensity** (time-averaged energy per unit area per unit time) [Optics $f2f$, Sec. 1.10] which is proportional to $|\underline{E}_0|^2$. The components of $\underline{E}_0$:

$$\underline{E}_0 = (E_{0x}, E_{0y}, E_{0z}) \ , \tag{3}$$

determine the **polarization**. Maxwell's equations require that for light propagating predominately along a particular direction (say z), the component of $\underline{E}_0$ in that direction is much smaller than the transverse components (e.g. $E_z \ll E_x$ and E_y) [Optics $f2f$, Sec. 2.4].[1] For light with a fixed polarization, we can replace the vector $\underline{E}_0$ with a scalar E_0 **scalar approximation** [Optics $f2f$, Sec. 2.5].

Outlook: In the next lecture, we shall look at the concept of phase, and introduce new notation in terms of complex numbers. We will also introduce the related concepts of wavefronts and spatial frequency.

[1] However, E_z is not zero for real fields, only for the mathematical idealisation known as a plane wave.