4. Derive an expression for the intensity transmitted through a Fabry-Perot etalon with mirrors of reflectivity R, as a function of the mirror separation d, the wavelength λ and the angle of incidence θ. Define the *finesse* and *free-spectral range*. [10]

A short etalon with mirrors of reflectivity $R = 0{\cdot}75$ is used as an interference filter transmitting infrared radiation of wavelength $4{\cdot}3\,\mu$m, at normal incidence. The full-width at half maximum of the transmitted intensity is about $\Delta\lambda = 0{\cdot}2\,\mu$m. Any phase change of the light on reflection may be neglected.

(a) Calculate the spacing of the mirrors.

(b) Calculate the change in mirror spacing required to shift the centre wavelength to $4{\cdot}5\,\mu$m.

(c) The mirror spacing is fixed at the value which gives maximum transmission at $4{\cdot}3\,\mu$m for normal incidence and the filter is tilted so that the angle of incidence becomes $17{\cdot}5^\circ$. Calculate the wavelength of the light transmitted.

(d) Find a wavelength longer than $4{\cdot}3\,\mu$m for which the intensity transmitted at normal incidence is a maximum, and a wavelength shorter than $4{\cdot}3\,\mu$m which also gives a maximum. Comment on how the transmission of other wavelengths affects the usefulness of the filter. [15]

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8. Consider the propagation of an electromagnetic wave in a homogeneous, isotropic, linear, non-conducting, non-magnetic medium of relative permittivity er. Give expressions for the velocity of propagation and for the refractive index of the medium in terms of ε_r and outline their derivation.

[4]

A linearly polarized plane wave of wavelength λ is travelling in air and is incident normally on a plane sheet of glass. Show that the ratio of the reflected to the incident electric field amplitude is

$$\frac{n_{glass} - n_{air}}{n_{glass} + n_{air}} .$$

where n_{air} and n_{glass} are the refractive indices of air and glass respectively. Estimate what fraction of the power is reflected from the sheet. [6]

The glass sheet is now coated on the incident side with a material with a refractive index $n_{coat} = (n_{air} n_{glass})^{1/2}$ and a thickness $d = \lambda/4$. Prove that there is now, in principle, no reflected power. Give one reason why, in practice, some reflected power is inevitable.

[5]

Simple materials with $n_{coat} < 1{\cdot}35$ are not readily available. Anti-reflection coatings often employ porous materials. Explain why very low values of power reflection can be achieved with such coatings. [5]

[Assume $n_{air} = 1{\cdot}0$ and $n_{glass} = 1{\cdot}5$.]

5. Explain what is meant by *polarized light* and describe the different types of polarization that are possible. Describe briefly the principle of operation of a polarizing device made from a birefringent material. [8]

A beam of light is elliptically polarized with the major axis vertical. The ratio of the major and minor axes of the ellipse is $a : b$. Explain how you would use a quarter-wave plate to obtain linearly polarized light, and determine the angle of the plane of polarization to the vertical. [6]

A beam of light consisting of a mixture of elliptically polarized and unpolarized light is passed through a linearly polarizing filter. The maximum of the transmitted light intensity is observed when the transmission axis of the filter is vertical, and is twice the minimum intensity. In a second experiment, the beam is passed through a quarter-wave plate with the fast axis vertical followed by the polarizing filter. The maximum is now observed when the transmission axis is at $33{\cdot}21°$ to the vertical. Calculate the ratio of the intensities of the polarized to unpolarized components of the light. [8]

How could the handedness of the elliptically polarized component be determined? [3]