1B24

WAVES OPTICS AND ACOUSTICS

REVISION LECTURE 2

Mainly Optics

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$$\mathtt{r} = \frac{Z_1 - Z_2}{Z_1 + Z_2} \tag{1}$$

$$\mathtt{t} = \frac{2Z_1}{Z_1 + Z_2}. \tag{2}$$

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Change of sign is phase change of π.

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1.2.2 b. in terms of impedance

Typical Part A question Note that the values of R and T give

$$R + T = 1, \tag{3}$$

which expresses the conservation of energy.

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Perfect transmission between two media, with no reflection, may be achieved by inserting a matching layer with an impedance which is the geometric mean of the impedances of the two original media, and with a thickness which is one quarter of a wavelength in the matching medium.

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This gives the phase velocity of the light.

2.2 Phase and group velocity

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Two waves - mathematics similar to that for beats.

2.2.2 envelope function and carrier

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for a wave travelling in the direction $\mathbf{k}/|\mathbf{k}|$ and with a wavelength $2\pi/|\mathbf{k}|$.

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2.3.4 Curvature of Wavefront

Negligible at large distances (Fraunhofer limit).

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$$f' = fc/(c - v_s).$$

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taking a positive velocity as being along the source-observer distance.

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Far from array, looking at an angle θ off axis, with sources h apart, phase difference δ between successive sources will be

$$\delta = \frac{2\pi}{\lambda} h \sin\theta.$$

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Finally,

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4.2.1 Diffraction grating

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Resolving power is

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where m is the order of diffraction and N is the number of lines in the grating.

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Every point on a primary wavefront serves as the source of spherical secondary wavelets.The amplitude of the field at any point is the superposition of all these wavelets, taking account of their amplitudes and phases.

5.3 Fraunhofer diffraction

The range at which wavefront curvature becomes important, the Rayleigh distance, for an aperture of width d is d^2/λ.

Ignoring the variation of amplitude with distance

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where α and β are the direction cosines of the ray travelling from the aperture to the point of observation.

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5.5 grating

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The grating is a pattern of N slits

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$$I(\theta) = I(0)\left[\frac{\sin\left(\frac{N\pi h}{\lambda}\sin(\theta)\right)}{N\sin\left(\frac{\pi h}{\lambda}\sin(\theta)\right)}\right]^2\left[\frac{\sin\left(\frac{\pi d}{\lambda}\sin(\theta)\right)}{\frac{\pi d}{\lambda}\sin(\theta)}\right]^2 .$$

6 Resolution of images

6.1 Rayleigh criterion for slit

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6.2 Rayleigh for circular aperture

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6.2 Rayleigh for circular aperture

For a circular aperture, the diffraction is circular, and the first zero occurs at an angle of $1.22\lambda/d$, where d is now the diameter of the aperture.

7 Reflection and Refraction

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7.1 Snel's law

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

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7 Reflection and Refraction

7.1 Snel's law

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

7.2 phase change on reflection

For small angles of incidence, zero for reflection from a less optically dense material, π for reflection from a more optically dense material.

7.3 Slab

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Slab of refractive index n_2 with a medium of refractive index n_1 on each side,

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Slab of refractive index n_2 with a medium of refractive index n_1 on each side, light is incident at an angle θ_1,

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$$\Delta = \frac{2dn_2}{\cos(\theta_2)}(1 - \sin^2(\theta_2)) = 2n_2 d \cos(\theta_2).$$

7.4 thin film

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where p is an integer.

7.5 Newton's rings

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The geometry is fairly simple

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7.6 wedge

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7.6 wedge

Straight fringes.

8 Michelson Interferometer

Arrangement:

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8.1 compensating plate for white light

Gives equal path lengths through glass for the two optical paths.

8.2 measuring refractive index

Putting a different material (e.g. a different gas) into one arm alters the optical path length.

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8.3 precise measurements of wavelength

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8.3 precise measurements of wavelength

Visibility of fringes varies with path length difference for a doublet source.

9 Fabry-Perot Interferometer

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Basic idea is to allow multiple reflections within a thin film. The arrangement of the Fabry-Perot interferometer uses two glass plates to form the reflecting surfaces. The pair of parallel plates is called an etalon.

With reflection and transmission coefficients for the two sides of the etalon r, r', t and t', With reflection and transmission coefficients for the two sides of the etalon r, r', t and t', and a phase difference δ for light passing through the gap at an angle θ to the normal

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$$I = I_0 \left(\frac{T}{1-R} \right)^2 \frac{1}{1 + F\sin^2(\delta/2)},$$

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where

$$T = tt' \qquad R = rr' \qquad F = \frac{4R}{(1-R)^2}.$$

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$$\frac{\lambda}{\Delta\lambda_{\min}} = \frac{\pi d}{\lambda}\sqrt{F}.$$

10 Geometric Optics

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- object, image, and centre of curvature distances are defined to be the x coordinates of the y, z planes which contain them.

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- object, image, and centre of curvature distances are defined to be the x coordinates of the y, z planes which contain them. Thus distances to points or planes to the right of the vertex or lens centre are positive, those to the left are negative.

- light sources and objects are placed to the left of the first surface in the system,

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- angles are taken to be positive or negative dependent on whether their tangents are positive or negative.

11 Refraction at spherical surfaces

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$$\frac{n_1}{l_1} - \frac{n_2}{l_2} = \frac{n_1 - n_2}{r}.$$

We need to insert the signs appropriate to our sign convention.

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11.1 Lenses

$$\frac{1}{v} - \frac{1}{u} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{1}{f}.$$

11.2 principal foci and focal length

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- one enters parallel to the optical axis and is refracted so as to pass directly or by projection through the second focal point;

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- one passes directly or by projection through the first focal point, and emerges parallel to the optical axis;

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In drawing ray diagrams, there are three principal rays:

- one enters parallel to the optical axis and is refracted so as to pass directly or by projection through the second focal point;
- one passes directly or by projection through the first focal point, and emerges parallel to the optical axis;
- one passes undeviated through the centre of the lens (where the lens surfaces are locally parallel).

11.3 Magnifying glass

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With the image at infinity

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With the image at infinity

with distances in mm.

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With the image at infinity

$$M = \frac{h'}{h}$$

with distances in mm.

11.3 Magnifying glass

With the image at infinity

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With the image at infinity

$$M = \frac{h'}{h} = \frac{250}{f},$$

with distances in mm. With the image at the near point

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With the image at infinity

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with distances in mm. With the image at the near point

$$M = \frac{250}{u} = 1 + \frac{250}{f}.$$

11.4 Cardinal or Principal points of thick lens system

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Same basic quantities as before – focal points and vertices of lenses

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Same basic quantities as before – focal points and vertices of lenses – but where do we measure them from? We define the so-called Cardinal Points or Principal Points as follows:

- two focal points, defined in terms of entry or exit rays parallel to the axis;

- principal planes, defined by the locus of the points of intersection of the incident ray through the focus and the exit ray parallel to the axis (Q_1 and Q_2);

- principal planes, defined by the locus of the points of intersection of the incident ray through the focus and the exit ray parallel to the axis (Q_1 and Q_2);
- the principal points, being the intersections of the principal planes with the axis;

- principal planes, defined by the locus of the points of intersection of the incident ray through the focus and the exit ray parallel to the axis (Q_1 and Q_2);
- the principal points, being the intersections of the principal planes with the axis;
- the nodal points where the ray through the optical centre of the lens (the ray which emerges parallel to its incident direction) intersects the axis.

11.5 Compound lenses

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Simply work through the analysis of the system step by step - as on problem sheet P20.

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Simply work through the analysis of the system step by step - as on problem sheet P20. Take the first lens, find the image it produces, take that image as the object for the second lens and calculate its position relative to the second lens taking into account the distance between the lenses.

11.5 Compound lenses

Simply work through the analysis of the system step by step - as on problem sheet P20. Take the first lens, find the image it produces, take that image as the object for the second lens and calculate its position relative to the second lens taking into account the distance between the lenses. Plug this result, adjusted where necessary in accordance with the sign convention, into the lens formula for the second lens

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Simply work through the analysis of the system step by step - as on problem sheet P20. Take the first lens, find the image it produces, take that image as the object for the second lens and calculate its position relative to the second lens taking into account the distance between the lenses. Plug this result, adjusted where necessary in accordance with the sign convention, into the lens formula for the second lens – and the job is done. Similarly, the overall magnification is the product of the magnifications produced by the individual lenses.

12 Optical Instruments

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12.2 astronomical telescope

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12.3 terrestrial telescope

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12.4 telephoto lens

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NOTE: the question will give you information about the arrangement of lenses — you don't have to remember them.