Sample Exam Questions - Module 4

1) Understanding the formation of coloured fringes in thin plates has posed a major challenge for theoreticians. In his *Opticks* (1704), Newton describes precise experiments (Newton's rings) and proposes a theory to explain them based on what he called "fits of easy reflection and transmission". Figures 1 and 2 stem from this work. Explain the basic elements of this theory as well as its strengths and weaknesses.

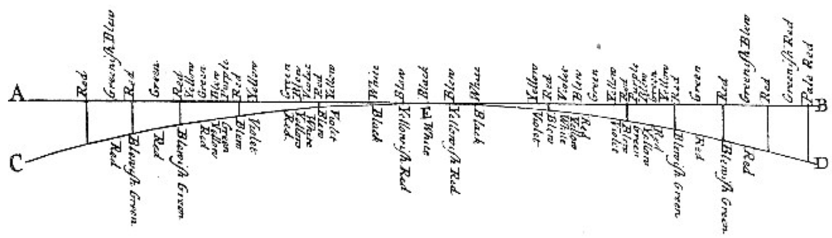

Figure 1: Colours and fits

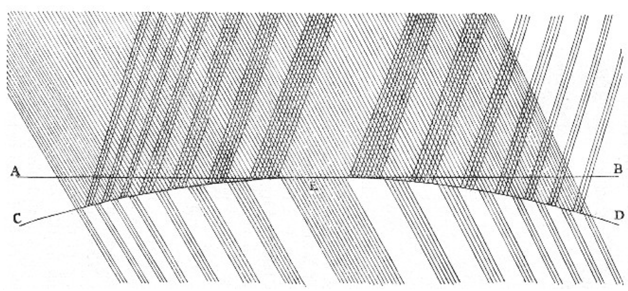

Figure 2: Thicknesses and fits

2) About one century after Newton, Young (1801) proposes a rather different, and yet more familiar, explanation for the coloured fringes which is based on an analogy between light and sound (see Figure 3). Explain the basic elements of this theory, as well as its strengths and weaknesses. Show how Young is able to derive equations that locate the points of maxima and minima for monochromatic light.

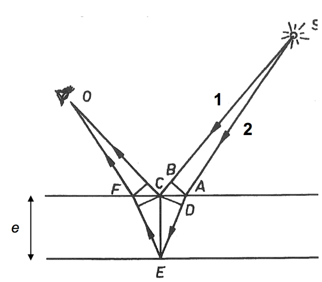

Figure 3: Young's explanation for interference fringes

3) Did Young perform Young's experiment? What are the arguments in favour and against this thesis?

4) Augustin-Jean Fresnel was responsible for giving a sharp mathematical formulation of Young's principle of interference (nowadays more known as the superposition principle). Central to Fresnel's solution of this problem is his quarter-wave decomposition. a) Why does Fresnel start his derivation by adding two "trains of waves" whose phase differ from another by $\lambda/4$, i.e., by $90°$? b) How this apparently specific example suffices to solve the general problem of adding waves with the same frequency but arbitrarily different phases? c) More precisely, show how Fresnel adds the oscillatory velocities (intensities) $a\sin(2\pi(t-\frac{x}{\lambda}))$ and $a'\sin(2\pi(t-\frac{x+c}{\lambda}))$ obtaining the result $A\sin[2\pi(t-\frac{x}{\lambda})-i]$. d) Fresnel mentions that "this is exactly the method employed in statics to find the resultant of any number of forces". Explain the reason for this analogy. e) This all seems weird and unnecessarily complicated to a modern reader. Which formalism do we use to add coherent waves nowadays and why is it simpler?

5) In comparison to Young's discrete formulas, Fresnel's approach is more powerful as it aims at determining the continuous spectrum of intensities (not only the points of maxima and minima). In sum, Fresnel mathematized Huygens' principle by deriving what we nowadays call Fresnel integrals to determine the resultant oscillatory intensity at a given point P. Figure 4 is crucial for his reasoning. a) Explain the conceptual idea behind this figure. b) Show the main steps that lead to his famous expression $(\int dz\cos(\pi\frac{z^2(a+b)}{ab\lambda}))^2+(\int dz\sin(\pi\frac{z^2(a+b)}{ab\lambda}))^2$. Note that $\frac{z^2(a+b)}{2ab}$ expresses the distance nS for the secondary wave emitted by a point of the wave front AM at a position z from the origin M.

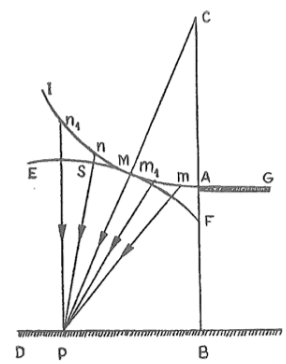

Figure 4: Fresnel's original derivation of Fresnel integrals

6) What were some of the most important observations that led to the notion of polarised light? What were the main challenges to its understanding?

7) Fresnel was also one of the main responsibles for solving the puzzle of polarisation. a) What important changes in his assumptions about the nature of light were needed for a better understanding of this phenomenon? b) How/Why does he use the principles of conservation of energy and momentum in his attempts to derive what we today call Fresnel equations? c) How would we derive them today?