Solution

Main questions

Huygens's principle states that each point on the surface of a phase front of a wave can be regarded as a source of spherical wavefronts, and the subsequent phase fronts can be constructed from the envelope formed by adding this together.

[If the examinee does not know Huygens's principle, it will be given to them so they can demonstrate their reasoning in the rest of the question.]

a. Only one slit.

The light from a narrow slit diffracts out in all directions, and so a screen at a very large distance would show essentially uniform illumination. [Note that, though the standard result for a slit of finite width is technically a "sinc" function, because the slit is stated as being much narrower than a wavelength, there really are no zeros in the actual pattern, because we never get to a condition of destructive interference between light from different parts of the slit.] Some students reasoned from their knowledge that there is a Fourier transform relationship between the field at the slits and the field in the far distance (or far field), reasoning that the slit is like an impulse, which transforms to a uniform distribution.

b. Two slits.

For two slits, this experiment is known as Young's two slit experiment. The result is that we see an interference pattern of alternating bright and dark stripes on a screen at a very large distance. This can be deduced from the notion of expanding circular phase fronts from the two narrow slit sources and the resulting interference at a screen at a very large distance. Again, some students reasoned from Fourier transforms to deduce that the transform of two impulse functions leads to a cosinusoidal tranform, which also explains the alternating bright and dark stripes.

c. A very large number of slits.

The result at a screen at a very large distance will be a set of relatively narrow beams at equally spaced angles. There are several ways this can be deduced. The standard way an optics person would likely go at this would be to consider the screen as a diffraction grating, and look at the directions that give constructive interference between the beams. Those knowing the Fourier transform relationship between the fields could reason that the The Fourier transform of a set of equally spaced impulses (or delta functions) is a set of equally spaced impulses (or delta functions). Another way of deducing the result is to consider the superposition of the interference patterns of slits of separation d and those of slits of separation $3d$, and those of separation $5d$, etc., thereby gradually building up the pattern for all the slits. The only angles for which these all add up in phase are the angles of strongest interference in the two beam case. This leads to a sharpening of the interference pattern from the two beam case, but no change in the position of the interference peaks. Again, this is equivalent to at set of beams at specific, equally spaced angles.