8. Mirror interference

1) For a position y, the arriving rays form an angle $\alpha = y/L$ (we use the small-angle approximation; the angle is in radians). Then, the optical path difference between the reflected and direct rays is $\Delta = 2l\cos\alpha \approx 2N\lambda - N\lambda\alpha^2$. Since there is an additional phase shift for the reflected rays at the reflection from optically denser dielectric material, the total phase shift is $\varphi = 2\pi\Delta/\lambda = 4\pi N - \pi(2N\alpha^2 - 1)$. At the maxima, this equals to $2\pi(2N - n)$, where n is an integer. Therefore, the condition for the maxima is written as

$$\alpha = \sqrt{\frac{n+0.5}{N}} \Rightarrow y_n = L\sqrt{\frac{n+0.5}{N}},$$

where $n = 0, 1, \ldots \ll N$.

2) Since the rays of a given order number n form a fixed angle with the x-axis, the maxima form on the screen concentric circles; the pitch between the neighbouring circles becomes smaller as the order number n grows (using the length unit defined by the smallest radius, the radii form a sequence $\sqrt{1} = 1$, $\sqrt{3} \approx 1.73$, $\sqrt{5} \approx 2.23$, etc).

3) Since the reflected rays can reach the screen only within a hemisphere, the phase shift varies between $\varphi_{\max} = 4\pi N + \pi$ and $\varphi_{\min} = \pi$. The number of maxima

$$m = (\varphi_{\max} - \varphi_{\min})/2\pi = 2N.$$