

NEWTON'S OPTICAL NOTEBOOKS: PUBLIC
VERSUS PRIVATE DATA

Newton's optical investigations, especially as gathered in his *Opticks* (1704), are widely regarded as representing a decisive, historical change in experimental practice. Recently I have been attempting to characterize the nature of his experimental research with more precision, and his laboratory "notebooks" have provided a revealing view of him at work in his laboratory. Newton's "laboratory notebooks," however, do not conform to our current conception of that term. In the first place, he did not carry out his experiments in a laboratory, but rather in his private rooms. In the second place, his notes are undated and, after the early years, unbound.¹ Newton did date some of his al/chemical experimental records, but as William Newman has shown in his paper, a tradition of dating alchemical records was apparently already established by Newton's day. The lack of dated entries in his notebooks has not been a serious impediment. Modern scholars can generally determine accurately the place of a document within a sequence of related ones, and establish its date to within a few months to a year or so.

Newton's records differ in a more fundamental way from laboratory notebooks, in that they were not intended as a permanent record of his experiments. He evidently discarded his raw experimental notes after an investigation was concluded and written up. The only sheet of raw data that survives is from his experiments on diffraction.² It most probably survived because it was part of his last, incomplete experimental investigation, and he expected to take it up at a later date. Theorizing, experimenting, and writing were part of a single process for Newton.³ In the early 1690's in composing those parts of the *Opticks* that represented new experimental research – those on the colors of thick plates and diffraction – he proceeded successively from draft to experiment to the deduction of new laws, and back to new drafts, and so on. For later reference he saved drafts, summaries, and preliminary papers as a record of his investigatory path. Raw data was apparently just that for Newton, raw. Data assumed significance for him only within a sequence of experiments and measurements and a broader context that explained the phenomenon and its properties.

Despite repeatedly denouncing hypotheses, Newton's experimental, optical research was in part theory driven, or to use his term, hypothesis driven. In each of

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his optical investigations – the colors thin films, diffraction, and the colors of thick plates – he formulated a physical model that was mathematizable and used it to devise experiments, deduce laws, control his measurements, and generally to conceive of the phenomenon. In the principal record that I will examine, “Of y^c coloured circles twixt two contiguous glasses,” most probably from 1671, Newton began with a sequence of propositions that he then succeeded in confirming experimentally.⁴ Many of these propositions were deduced from his physical model based on hypothetical entities, light corpuscles and vibrations of the aether, and some proved to be erroneous. That Newton found them to be erroneous by further experimentation shows that he would readily abandon a physical model if the experimental evidence was sufficiently convincing.

His notebooks show Newton trying to integrate physical explanation, mathematical description, and experimental results, and an unrelenting quest to eliminate sources of error. As we shall see, however, he suppressed much of the most exciting parts of his quantitative research and left few clues for subsequent generations on how to carry out mathematical and quantitative experimental research. His accounts of his qualitative experimental investigations – most notably, the theory of light and color that ultimately formed Book I of the *Opticks* – were, on the contrary, sufficiently detailed to serve as an exemplar for later generations. My concern will be both with the experimental methods by which Newton achieved his results and the dilemmas he subsequently confronted in presenting them publicly.

“Coloured Circles” is a working paper intended for his own use. There is some evidence that the data were not directly entered here until Newton convinced himself of their meaningfulness. On a few occasions he tells us they are only a sampling of his measurements. For example, he wrote “Suspecting y^t y^c pressure might much vary y^c glasses figures I tryed wthout pressing them together, & y^t many times . . . *Two or three of the observatio[ns] follow.*”⁵

“COLOURED CIRCLES”

It is unnecessary to retrace the history of the colors of thin films here, but it should be noted that Newton learned about them from Hooke’s account in the *Micrographia* of the colors seen in sheets of mica.⁶ Hooke had conjectured that the appearance of the colors was periodic, though he confessed he was unable to measure the thickness of such thin films to demonstrate this property. Newton’s key breakthrough was his insight that if he put a lens (which is really just a segment of a circle) on a glass plane, then by a principle from Euclidean geometry on the tangents to circles (Euclid’s *Elements*, III, 36) he could readily determine the thickness of the thin film of air formed in the gap between them simply by measuring the circles’ diameter. If in Figure 1 a convex lens *ABC* is placed on a glass plate *FBG* and illuminated and viewed from above, a set of concentric colored circles – now aptly known as Newton’s rings – produced by the thin film of air *ABCGBF* will be seen through the upper surface of the lens.

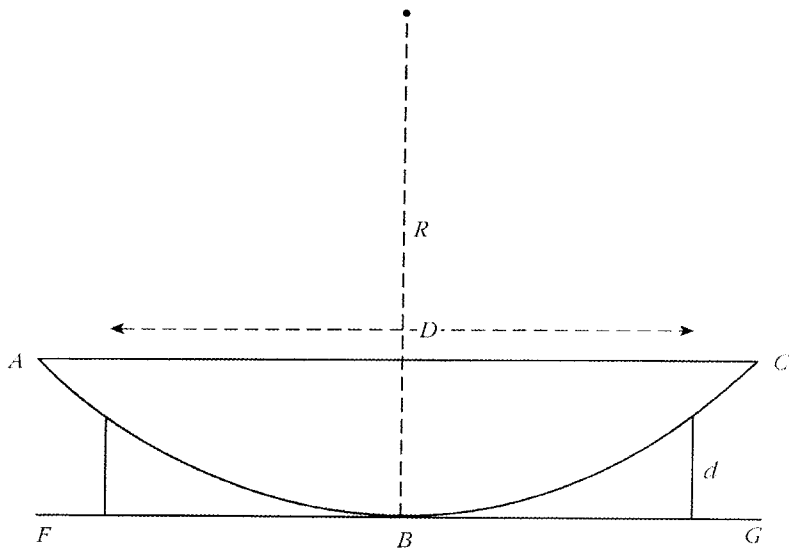


Figure 1. Newton's method for determining the thickness d of a thin film of air between a spherical lens and a plane.

The circles in Figure 2 will form an alternating sequence of bright and dark rings and their common center, the point of contact A , will be surrounded by a dark spot.

Let the diameter of a colored circle in Figure 1 be denoted by D , the thickness of the air film producing that circle by d , and the radius of the lens by R . Then by Euclid's theorem $d = D^2/8R$. To establish that the circles do appear at integral multiples of some definite thickness, or that the appearance of the colors is a periodic phenomenon, Newton simply had to measure the diameter of successive circles and see if their squares increased as the integers. He found that the thickness of the film for successive circles does increase in arithmetic progression, or expressed in the modern form of an equation,

$$d = \frac{D^2}{8R} = \frac{mI}{2}, \tag{1}$$

where I is an interval such that for m odd the ring is a bright one and for m even a dark one. As I shall explain later, in Newton's physical model I represents the pulse length of a vibration of the aether, although publicly he would interpret this length as the experimentally observed value of the thickness of the film producing a particular color.

In his numerous descriptions of this experiment, Newton says surprisingly little about the experimental arrangement that he used. We know little more than that he built some kind of a frame for the glasses, which were tied together, that he measured the diameters of the colored circles with a compass, and that he believed