DVD

Goals: Use physics knowledge to check media descriptions for consistency. Apply rules for interference and diffraction to a physical device.

PROBLEM

The digital video disk (DVD) is a standard medium for storing information such as movies, music, or software. The DVD is made from multiple layers of polycarbonate plastic which includes one or more layers with encoded information. The encoded information is read using the diffraction of light. The diffraction from a DVD can be seen when it is held under light and a spectrum of colors appears. (Photo engagetHD.com)

The DVD is a widespread technology and is well documented on the internet. In this lab you will check the facts from one internet site to see how well the description of a DVD matches the physics of the device.

PROBLEM SKILLS

When coherent light from a laser is reflected off two surfaces at different distances it can the light can be subject to either constructive or destructive interference. If a surface is at a distance to reflect a wavelength λ with constructive intereference then the light will have destructive intereference when twice the difference in distance *d* is equal to a phase shift of 180^{o}. This can be expressed mathematically as

$$2d = \left(m + \frac{1}{2}\right)\lambda \qquad \textbf{(EQ 1)}$$

where *m* is an integer.

Interference need not be completely constructive or destructive. For an arbitrary wavelength shift *L*, the phase difference $\Delta\phi$ in radians is

$$\Delta\phi = \left(\frac{L}{\lambda} - m\right)2\pi \qquad \textbf{(EQ 2)}$$

The length of a spiral depends on its inner radius R_1, outer radius R_2 and the change in radius Δr with each turn of the spiral. If the average circumference of one turn of a spiral is $2\pi(R_1 + R_2)/2$ and the number of turns is $(R_2 - R_1)/\Delta r$, then the length *S* is approximately

$$S = 2\pi\left(\frac{R_1 + R_2}{2}\right)\left(\frac{R_2 - R_1}{\Delta r}\right) = \frac{\pi(R_2^2 - R_1^2)}{\Delta r} \qquad \textbf{(EQ 3)}$$

is the difference inchanged When The extra patit can In the real world there are multiple sources of fields superposed on each other. These fields can be considered background noise to the signal field from the earth. One technique to estimate the effect of noise sources is to consider a worst case scenario. If the field from the background source is greater that 1/10 of the signal then it might be something to worry about for measurements with no more than one significant figure of accuracy.

A current in a wire produces a magnetic field (*B*) measured in tesla. If the current (*I*) in a long straight wire is measured in amps, the field at a distance (*r*) in meters is:

BACKGROUND INFORMATION

The web site HowStuffWorks.com has a detailed description of DVD technology. The technology consists of two parts: the player and the disk. The following facts are condensed from that web site.

The DVD player has three parts. There is a variable speed motor that spins the disk at 200 to 500 rpm. There is a laser with a wavelength of 640 nm that reflects of the mirrored surface of the DVD and is measured by an optical pickup that can tell the difference in reflectivity between the flat surface of the disk an small bumps on it. Finally there is a tracking motor that positions the laser at a particular radius from the center of the disk and slows the DVD down from 500 rpm when it is tracking the innermost part of the data down to 350 rpm at the outermost part of the disk.

The simplest DVD disk is a single-layer single-sided disk with a diameter of 12 cm. The data layer has track for the data that starts near the center of the disk and spirals outward with a radial spacing of 740 nm between lines of data. Each bit of data fills an area that is 400 nm long and 320 nm wide. The data bit can either be at the normal surface level or raised by 120 nm. The web site says that a single spiral track is 12 km long and holds 4.7 gigabytes of data (1 byte equal 8 bits).

PROBLEM SOLVING

Part A. Interference

1. Solve EQ 1 for m in terms of d and λ.
2. Use the result of step 1 and the given data to solve for m. Round m to the nearest whole integer.
3. Determine the total path difference L and use the integer value of m in step 2 with EQ 2 to find the phase difference for laser light reflected off the DVD bumps.
4. Convert the phase difference from step 3 into degrees.
5. Use EQ 1 with your integer value of m to find a depth d that would give complete destructive interference.
6. Consider the number of significant figures in the given data to round your result from step 5 to the same number of significant figures.
7. Share your results from part A with the other groups and discuss any differences between the groups and the accuracy of the data from the web site.

Part B. Capacity

8. Estimate the inner and outer radius of a DVD spiral track.
9. Use EQ 3 to determine the length of the spiral based on the given data and your estimates from step 8.
10. Compare the result from step 9 with the claimed length from the web site.
11. Rearrange EQ 3 to solve for the inner radius.
12. Use the equation from step 11 to find a value for the inner radius consistent with the given data.
13. Convert the given data storage value into bits.
14. Use the given length of a data bit to determine the total length needed to hold the given amount of data.
15. Compare the result from step 14 with the given length and the result from step 9.
16. Share your results of part B with the other groups and discuss any differences between the groups.

OBSERVATIONS

For each observation below write a short paragraph to explain your thinking.

The picture shows a whole spectrum of color, yet the DVD is designed for one frequency of laser light. What is causing a spectrum of color in the picture?

Could rounding errors or significant figures account for any discrepancies in the data given by the web site if complete destructive interference is assumed?

How consistent were the different groups analyses of the web site's values to give destructive interference? Is this a good way to check a source for consistency with physics?

How well did your group's first estimate of inner radius in step 8 match with the recalculated value in step 12?

Is your length to hold the data in step 14 consistent with either of the lengths of the spiral compared in step 10?

Could more data be placed in a single spiral on one DVD?