SI Physics - Full Discipline Demo

Diffraction Grating

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term to the best description.

- Coherent
- Diffraction
- Grating
- Interference
- Specular dot

1. Composed of numerous narrowly spaced parallel slits or grooves
2. Having the same wavelength, frequency, and in-phase
3. Interaction of waves where they meet in space
4. The bending of waves near a boundary or as a wave passes through an opening
5. The zeroth order direct reflection fringe

Correct answers:

1 Grating 2 Coherent 3 Interference 4 Diffraction

5 Specular dot

Categorize each term as relating to diffraction or interference.

- Constructive
- Destructive
- Fringe pattern
- Huygens' principle
- In-phase
- Shadow region

Diffraction	Interference
1	2

Correct answers:

1 Huygens' principle Shadow region

2 Constructive Destructive Fringe pattern In-phase

Categorize each statement as true or false.

As the fringe order increases for a diffraction grating the fringe brightness decreases.

The fringes of a grating are sharper than those of a double slit.

The interference pattern produced by the double experiment looks very different than the pattern produced by a diffraction grating.

The path difference for a bright fringe is half-integer wavelengths.

True	False
1	2

Correct answers:

1

As the fringe order increases for a diffraction grating the fringe brightness decreases.

The fringes of a grating are sharper than those of a double slit.

2 The path difference for a bright fringe is half-integer wavelengths.

The interference pattern produced by the double experiment looks very different than the pattern produced by a diffraction grating.

Exploration

_____ light has the shortest wavelength of the visible spectrum.

- Red
- Yellow
- Blue ✔
- All of the above

The line drawn connecting the crests of several waves and perpendicular to the direction of wave motion is the _____.

- transverse wave
- wavefront ✔
- wavelength
- None of the above

Diffraction only occurs for waves, not particles.

- True ✔
- False

_____ is the interaction of waves where they meet in space.

- Interference ✔
- Diffraction
- Wavefront
- None of the above

_____ interference occurs when the crest of one wave aligns with the trough of another.

- Constructive
- Destructive ✔
- Coherent
- None of the above

A _____ grating is composed of slits and light passes through the grating to create a diffraction pattern.

- diffraction
- interference
- transmission ✔
- None of the above

The grooves etched in a CD act as a(n) _____ grating.

- interference
- reflection ✔
- transmission
- None of the above

The zeroth order direct reflection fringe of a reflection grating is also called the _____.

- incident fringe
- reflection dot
- specular dot ✔
- None of the above

Blue light interferes at a larger angle than red light in a diffraction grating.

- True
- False ✔

Exercise 1

How closely did your calculated line density in Data Table 1 match the reported line density on the diffraction grating card? What assumptions were made and what factors contributed to error in your calculation?

Student answers will vary. The calculated line density was very close to the reported line density, producing a percent error of 4.0%. An assumption was made with the wavelength of red light produced by the laser – the laser pointer wavelength is given as a range of nearly 80 nm. 633 nm was a wavelength chosen within the range but does not necessarily match the exact wavelength produced by the laser. The wavelength is an integral part of the line density calculation and variance in the wavelength used for the calculations can have a significant impact on results. An additional experimental factor contributing to error could be that the diffraction grating was not parallel to the wall. This would make the interference pattern less symmetric, skewing measurements and resulting calculations.

Did your calculated wavelength in Data Table 2 fall within the expected wavelength range for red light? Explain any factors affecting measurement and calculations in Part 2.

Student answers may vary. The calculated wavelength in **Data Table 2** lies within the red region of the visible light spectrum. A major factor affecting error is identifying where the center of the red region and white central region is on Paper 4. Inaccurately identifying the red region would result in wavelengths closer to orange or infrared light.

What color of laser light shines through a diffraction grating with a line density of 500 lines/mm if the third maxima from the central maxima (m=3) is at an angle of 45°? Show all work in your answer.

Hint: Calculate the wavelength then use Table 1 to identify the color.

The equation that must be used is: $d*\sin\Theta=m\lambda$ or $d*\sin\Theta/m=\lambda$
$d=1/n=1/500$ lines/mm$=0.002$ mm
$\Theta=45°$ and $m=3$
So, $0.002*\sin(45)/3=0.002$ mm$*0.707/3 = 0.00471$ mm $= 471$ nm
471 nm corresponds to **blue light**, which has the range 450 nm – 495 nm.

How would the interference pattern produced by a diffraction grating change if the laser light changed from red to blue?

The equation describing interference patterns is d*sinΘ=mλ. Assuming d and m are unchanging, this leaves the relation sinΘ ~ λ. Blue has a shorter wavelength than red, so changing the light from red to blue would decrease λ and thus decrease sinΘ. A decrease in sinΘ corresponds to a decrease in Θ, which results in the interference pattern being compressed. That is, the maxima in the interference pattern will be more closely spaced for blue light compared to the maxima produced with red light.

Data Table 1: Determining Line Spacing of a Diffraction Grating
(SAMPLE ANSWER BELOW)

λ (nm)	633
L (mm)	123.9
Δx_1 (mm)	110.7
Δx_2 (mm)	106.2
Θ_1 (°)	41.8
Θ_2 (°)	40.6
d_1 (mm)	0.00095
d_2 (mm)	0.00097
d_{avg} (mm)	0.00096
Calculated Line Density n (Lines/mm)	1040
Reported Line Density n (Lines/mm)	1000
Percent Error (%)	4.0

Data Table 2: Determining the Wavelength of Red Light Using a Diffraction Grating
(SAMPLE ANSWER BELOW)

n (Lines/mm)	1000
d (mm)	0.001
L (mm)	100.1
Δx_1 (mm)	100.9
Δx_2 (mm)	112.00
Θ_1 (°)	45.2
Θ_2 (°)	48.2
λ_1 (mm)	710
λ_2 (mm)	746

λ_{avg} (mm)	728
λ_{theory} (mm)	620-750
Lies in Region? (Yes/No)	Yes

Exercise 2

How similar is the CD's groove number in Data Table 3 to the typical value of 625? What factors would affect any discrepancies?

Calculated groove number is similar to the typical value of 625, varying only by 24, or ~4%. Factors affecting discrepancies include the assumption of the laser light being 633 nm (as opposed to the range printed on the laser pointer) and the amount of data stored on the CD – the length of the CD can affect the groove number.

How do the interference patterns produced by a CD and diffraction grating compare? Explain similarities, differences, and causes in your answer.

The interference patterns produced by the CD and diffraction grating are similar in that they both produce interference patterns with bright regions of constructive interference. They differ in that the diffraction grating produces a central maxima framed by other maxima of different order, symmetric on each side, whereas the CD produces one bright central maxima on the bottom with maxima of different orders above (with no maxima below). The main difference between the two is that the diffraction grating transmits light, producing a symmetric pattern, while the CD reflects light, producing only one side of the typical diffraction pattern seen with the diffraction grating.

Dtat Table 3: Determining Groove Spacing for a Compact Disk

(SAMPLE ANSWER BELOW)

λ (nm)	633
L (mm)	97.0
h_0 (mm)	31.5
h_1 (mm)	153.5
Θ_0 (°)	18.0
Θ_1 (°)	57.7
d (mm)	0.00152

Calculated Line Density n (Lines/mm)	659

Competency Review

_____ is the bending of waves as they pass by a barrier or through an opening.

- Interference
- Coherence
- Diffraction ✔
- None of the above

For two waves to interfere, they must be _____.

- diffracted
- coherent ✔
- in phase
- None of the above

The pattern of bright and dark fringes that appears on a viewing screen after light passes through a single slit is called a(n) _____ pattern.

- diffraction
- interference ✔
- transmission
- None of the above

The bright fringe that appears directly across from the slit in the single slit experiment is the _____ order fringe.

- zeroth ✔
- first
- principle
- None of the above

The path length difference for the waves exiting the two slits of the double slit experiment must be equal to _____ for a bright fringe to appear.

- one wavelength
- one-half wavelength
- an integer number of wavelengths ✔
- None of the above

When white light is used in the double slit experiment, the first order and higher bright fringes appear _____.

- white
- as a rainbow ✔
- red
- None of the above

The fringes of a diffraction grating are narrower and sharper than the fringes of the double slit experiment.

- True ✔
- False

It is more useful to know the _____ for a diffraction grating.

- line density ✔
- spacing between the lines
- number of lines
- None of the above

The smaller the spacing between the lines of a diffraction grating, the _____ the fringes.

- broader
- fainter
- narrower ✔
- None of the above

The smaller the spacing between the lines of a diffraction grating, the _____ the fringes.

- more spread out ✔
- more compact
- greater the number of
- None of the above

Short wavelengths of light passed through a diffraction grating create fringes that are _____ than long wavelengths of light.

- more spread out
- more compact ✔
- brighter
- None of the above

The spacing of the diffraction pattern on a viewing screen does not depend on the distance from the diffraction grating to the screen.

- True
- False ✔

A transmission diffraction grating produces a diffraction pattern with the first order angle at 35 degrees when light with a wavelength of 600 nm is used, meaning the grating has _____ lines/mm.

- 0.001
- 956 ✔
- 1046
- None of the above

The path length difference between the zeroth order bright fringe and the first order bright fringe of a diffraction grating is _____.

- zero
- one-half wavelength
- one wavelength ✔
- None of the above

A diffraction grating with 1000 lines per millimeter has a first order diffraction angle of 25 degrees, so the wavelength of light being used is _____ nm.

- 423 ✔
- 0.0004
- 250
- None of the above

When passing white light through a diffraction grating, the central bright fringe appears _____.

- as a rainbow
- as white light ✔
- dark
- None of the above

The number of lines per millimeter of a reflection diffraction grating can be calculated using the same formula as for the transmission diffraction grating.

- True
- False ✔

For reflection diffraction gratings, it is necessary to determine the _____ in order to calculate the line density of the grating.

- reflection angle
- diffraction angle
- wavelength of light
- All of the above ✔

Extension Questions

How would the interference pattern change for this experiment if a. the grating was moved twice as far from the screen and b. the line density of the grating were doubled? Refer to the diffraction grating equations in your answer. (SAMPLE ANSWER BELOW)

a. If the screen were twice as far away, the pattern would be twice as spread out with larger spacings between the bright fringes. This is clearly seen from the equation h=Ltan(theta). If L is doubled and theta is constant, h must also double. b. If the line density of the grating doubles, the slits are half as far apart, so the bright fringes will be brighter, narrower, and more spread out. This is clear from the equation dsin(theta)=mlambda. sin(theta) must double if d is halved. This leads to more than doubling theta, so the spacing of the fringes is more than doubled following the equation h = Ltan(theta).