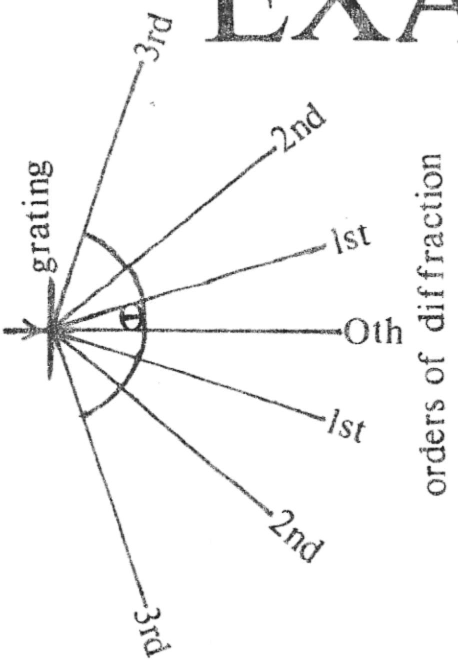
DIFFRACTION EXAMPLES



Light from a He-Ne laser with wavelength of 633 nm encounters a diffraction grating with a spatial frequency of 500 lines/mm. To what angles does the light get diffracted? Spatial frequency of 500 lines/mm = fringe spacing of 1/500 mm = .002 mm = 2 μm = 2000 nm. The diffraction equation is $m\lambda = d \sin\theta$, which changes to $m\lambda/d = \sin\theta$.

For the first order, m = 1, λ = 633 nm, d = 2000 nm

$\sin\theta$ = 1 x 633 nm / 2000 nm = .3165

$\sin\theta$ = .3165, θ = 18.5°.

For the second order of diffraction everything is the same except that now m = 2, so

$\sin\theta$ = 2 x 633 nm / 2000 nm = .633

$\sin\theta$ = .633, θ = 39.3°.

For the third order, m = 3, so

$\sin\theta$ = 3 x 633 nm / 2000 nm = .9495

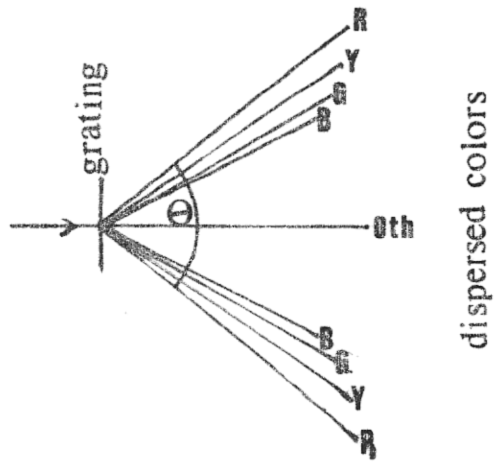
$\sin\theta$ = .9495, θ = 71.7°.

Fourth order, m = 4,

$\sin\theta$ = 4 x 633 nm / 2000 nm = 1.266. There is no angle with sine greater than 1, so there is no fourth order of diffraction for this grating at this wavelength.

If the fringe spacing, d, were smaller, like 1000 nm, then first order diffraction would have an angle of 39.3°. Second order of diffraction ends up with a sine greater than one, so there is no second order in this instance. Generally for a given wavelength the higher the spatial frequency, which means a smaller fringe spacing, the larger the angle of diffraction.

One method of separating the colors from a multi-line laser is to pass the undifferentiated beam through a diffraction grating. For a Krypton ion laser tuned to these four colors, the dispersion can be predicted by solving the grating equation four times.



Let d = 1000 nm

First order diffraction m = 1

BLUE: λ = 457 nm

$\sin\theta$ = 1 x 457 nm / 1000 nm = .457

$\sin\theta$ = .457, θ = 27.2°.

GREEN: λ = 514 nm

$\sin\theta$ = 1 x 514 nm / 1000 nm = .514

$\sin\theta$ = .514, θ = 30.9°.

YELLOW: λ = 568 nm

$\sin\theta$ = 1 x 568 nm / 1000 nm = .568

$\sin\theta$ = .568, θ = 34.6°.

RED: λ = 647 nm

$\sin\theta$ = 1 x 647 nm / 1000 nm = .647

$\sin\theta$ = .647, θ = 40.3°.

The angle of diffraction is dependent not only on the grating spacing, but on the color or wavelength of the light incident on the grating. Short wavelengths, the blues, are bent less than the longer wavelengths, from green to yellow to red. This is called dispersion through a diffraction grating. White light can be broken up into all its components through a grating producing a continuous spectrum.

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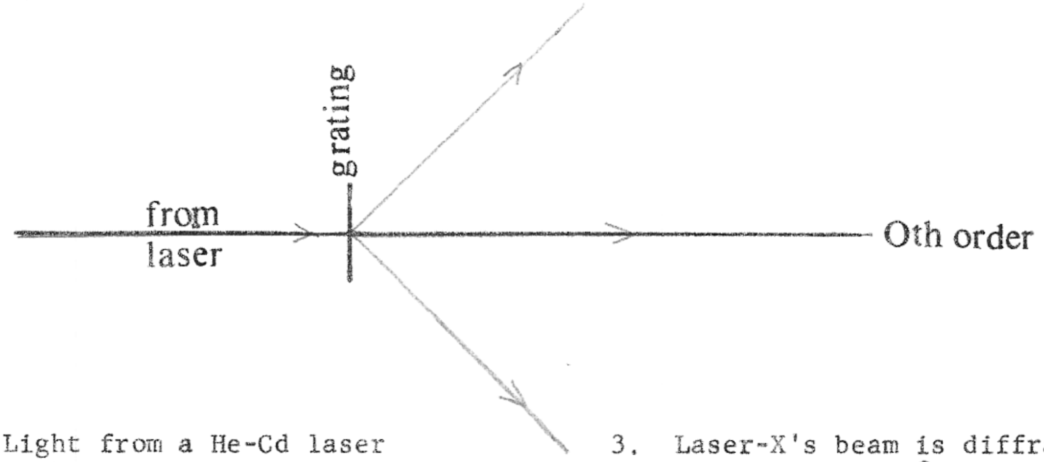
DIFFRACTION PROBLEMS

Use your pocket calculator, protractor, colored pencils and the diffraction grating equation to solve these problems. ($m\lambda = d \sin \Theta$, where m = the number of the order of diffraction, λ = the wavelength of the light, d = the grating spacing, and Θ = the angle between the diffracted light and the normal to the grating.)

1. A pulse of Ruby laser light (694 nm wavelength) falls perpendicularly on a grating with spacing of 1 μm. (Don't forget to change all lengths to the same units!) Find Θ for all the possible orders and draw them.



2. Light from a He-Cd laser (λ = 441 nm) is diffracted by an angle of 25° for the first order. What is the grating spacing d?

1043.5 nm

3. Laser-X's beam is diffracted through an angle of 45.7° through the grating in problem 1 for its second order. What is its wavelength?

357.8 nm

4. A light show wishes to separate the blue 458 nm line and the green 514 nm line from their Argon ion laser. For a grating whose spacing is 2000 nm, draw all the orders of diffraction for these two wavelengths.