$1m = 100 cm$ $1m = 1{,}000{,}000{,}000 = 1\times10^9 nm$ $100 cm = 1\times10^9 nm$ $1 cm = 1\times10^7 nm$

Name: Period: Date:

Diffraction Worksheet

Formulas: **N = 1/d** $d = \frac{1}{N}$ $\sin\theta = N \cdot m \cdot \lambda$ **dsinθ = mλ** $\frac{\sin\theta}{N} = m\lambda$

Where N = # of lines per centimeter; d = line spacing on diffraction grating; θ = angle; m = order #; λ = wavelength

1. A diffraction grating has $8.00 \times 10^3$ lines per centimeter. (N=8000)
   a. What is the slit spacing in this grating?

   $d = \frac{1}{N} = \frac{1}{8000 \text{ lines/cm}} = 1.25\times10^{-4}$ cm/line

   b. Is the grating appropriate for observing diffraction of visible light (400 to 700 nm)? m=1

   $\lambda = 400 nm\left(\frac{1 cm}{1\times10^7 nm}\right) = 4\times10^{-5} cm$ $\sin\theta = \frac{m\lambda}{d} = \frac{(1)(4\times10^{-5} cm)}{1.25\times10^{-4} cm} = .32$ $\theta = \sin^{-1}(.32)$ $\theta = 18.7°$

   $\lambda = 700 nm\left(\frac{1 cm}{1\times10^7 cm}\right) = 7\times10^{-5} cm$ $\sin\theta = \frac{m\lambda}{d} = \frac{(1)(7\times10^{-5} cm)}{1.25\times10^{-4} cm} = .56$ $\theta = 34.1°$

2. The spacing in a diffraction grating is $8.00 \times 10^{-6}$ m. = d
   a. How many lines per centimeter are there?

   $d = 8\times10^{-6} m\left(\frac{100 cm}{1 m}\right) = 8\times10^{-4} cm$ $N = \frac{1}{d} = \frac{1}{8\times10^{-4} cm} = 1250$ lines/cm

   b. Find the first, second and third angles at which one would observe maxima when light of 620 nm is diffracted. m=1, 2, 3

   $\lambda = 620 nm = 6.2\times10^{-5} cm$

   1st order: $\sin\theta = \frac{m\lambda}{d} = \frac{(1)(6.2\times10^{-5})}{8\times10^{-4}}$ $\theta = 4.44°$

   2nd order: $\sin\theta = \frac{(2)(6.2\times10^{-5})}{8\times10^{-4}}$ $\theta = 8.92°$

   3rd order: $\sin\theta = \frac{(3)(6.2\times10^{-5})}{8\times10^{-4}}$ $\theta = 13.44°$

3. The second-order maxima are observed at 8.12° with the grating above in a diffraction experiment. What is the wavelength?

   m=2
   θ=8.12°
   $d = 8\times10^{-4} cm$

   $\lambda = \frac{d\sin\theta}{m} = \frac{(8\times10^{-4} cm)\sin 8.12°}{2} = 5.65\times10^{-5} cm = 565 nm$

4. A diffraction grating with $2.500 \times 10^3$ lines/cm is used to examine the sodium spectrum. Calculate the angular separation of the two closely spaced yellow lines of sodium (588.995 nm and 589.592 nm) in each of the first three orders. (Hint: wavelength = the difference of the two lines: 589.592 nm – 588.995 nm = 0.597 nm)

   m=1 θ=? m=2 θ=? m=3 θ=?
   $N = 2.500\times10^3$ lines/cm
   $d = 4\times10^{-4} cm$

   $\lambda = .597 nm\left(\frac{1 cm}{1\times10^7 nm}\right) = 5.97\times10^{-8} cm$

   $\sin\theta = \frac{m\lambda}{d}$

   1st: $\sin\theta = \frac{(1)(5.97\times10^{-8} cm)}{4\times10^{-4} cm}$ $\theta = .00855°$

   2nd: $\sin\theta = \frac{(2)(5.97\times10^{-8} cm)}{4\times10^{-4}}$ $\theta = .0171°$

   3rd: $\sin\theta = \frac{(3)(5.97\times10^{-8})}{4\times10^{-4}}$ $\theta = .0257°$

5. A grating of unknown spacing diffracts monochromatic light of 570 nm. The third-order maxima are observed at a 23° angle. What is the spacing in that grating?

$N = 2285$ lines/cm

$d = ?$
$\lambda = 570\text{ nm} = 5.70\times10^{-5}\text{ cm}$
$\theta = 23°$
$m = 3$

$d\sin\theta = m\lambda$

$d = \frac{m\lambda}{\sin\theta} = \frac{(3)(5.70\times10^{-5})}{\sin 23°}$

$4.38\times10^{-4}\ \frac{\text{cm}}{\text{line}}$

6. A diffraction grating with 4525 lines/cm is illuminated by direct sunlight. The first-order solar spectrum is spread out on a white screen hanging on a wall opposite the grating.
   a. At what angle does the first-order maximum for blue light with a wavelength of 422 nm appear?

$422\text{ nm}\left(\frac{1\text{ cm}}{1\times10^{7}\text{ nm}}\right)$

$\lambda = 4.22\times10^{-5}\text{ cm}$
$m = 1$
$N = 4525\ \frac{\text{lines}}{\text{cm}}$
$d = \frac{1}{4525} = 2.21\times10^{-4}$ cm/line

$\sin\theta = \frac{m\lambda}{d}$

$\sin\theta = \frac{(1)(4.22\times10^{-5})}{2.21\times10^{-4}}$

$\sin\theta = .191$ $\theta = 11.0°$

-or- $\sin\theta = N\cdot m\cdot\lambda$
$\sin\theta = (4525)(1)(4.22\times10^{-5})$
$\sin\theta = .191$

   b. At what angle does the first-order maximum for red light with a wavelength of 655 nm appear?

$\lambda = 6.55\times10^{-5}\text{ cm}$
$m = 1$
$N = 4525$ lines/cm
$d = \frac{1}{4525} = 2.21\times10^{-4}$ cm/line

$\sin\theta = \frac{m\lambda}{d}$

$\sin\theta = \frac{(1)(6.55\times10^{-5})}{2.21\times10^{-4}} = .296$

$\theta = 17.2°$

-or- $\sin\theta = N\cdot m\cdot\lambda$
$\sin\theta = (4525)(1)(4.22\times10^{-5})$
$\sin\theta = .296$

7. A grating with 1555 lines/cm is illuminated with light of wavelength 565 nm. What is the highest order number that can be observed with this grating? (Hint: Remember that sin θ can never be greater than 1 for a diffraction grating.)

$\theta = 90°$
$\lambda = 5.65\times10^{-5}\text{ cm}$
$N = 1555$ lines/cm
$d = 6.43\times10^{-4}\text{ cm}$

$m = \frac{d\sin\theta}{\lambda} = \frac{(6.43\times10^{-4})\sin 90°}{5.65\times10^{-5}}$

$m = 11.4$ $11^{th}$ order

8. Repeat problem #7 for a diffraction grating with 15,550 lines/cm that is illuminated with light of wavelength 565 nm.

$\theta = 90°$
$N = 15{,}550$ lines/cm
$\lambda = 5.65\times10^{-5}\text{ cm}$
$d = 6.43\times10^{-5}\text{ cm}$

$m = \frac{d\sin\theta}{\lambda} = \frac{(6.43\times10^{-5})\sin 90°}{5.65\times10^{-5}}$

$m = 1.14$ $1^{st}$ order

9. A diffraction grating is calibrated using the 546.1 nm line of mercury vapor. The first-order maximum is found at an angle of 21.2°. Calculate the number of lines per centimeter on this grating.

$\lambda = 5.461\times10^{-5}\text{ cm}$
$m = 1$
$\theta = 21.2°$
$N = ?$

$d = \frac{m\lambda}{\sin\theta} = \frac{(1)(5.461\times10^{-5}\text{ cm})}{\sin 21.2°}$

$d = 1.51\times10^{-4}\text{ cm}$

$N = \frac{1}{d} = 6.62\times10^{3}$ lines/cm

-or- $N = \frac{\sin\theta}{m\lambda}$

$N = \frac{\sin 21.2°}{(1)(5.461\times10^{-5})}$

$N = 6.62\times10^{3}$