

## SOLUTIONS

---

**1. A diffraction grating has lines spaced  $2.00 \mu\text{m}$  apart. Let's consider white visible light (wavelengths ranging from  $0.400 \mu\text{m}$  for violet light to  $0.700 \mu\text{m}$  for red light) shining on it.**

**(a) Determine all the angles for which interference maxima occur for violet light.**

$$\sin \theta = m\lambda/d = m(0.400 \mu\text{m})/(2.00 \mu\text{m}) = m(0.200)$$

$$m = 0 \Rightarrow \sin \theta_0 = 0 \Rightarrow \theta_0 = 0^\circ$$

$$m = 1 \Rightarrow \sin \theta_1 = 0.200 \Rightarrow \theta_1 = 11.5^\circ$$

$$m = 2 \Rightarrow \sin \theta_2 = 0.400 \Rightarrow \theta_2 = 23.6^\circ$$

$$m = 3 \Rightarrow \sin \theta_3 = 0.600 \Rightarrow \theta_3 = 36.9^\circ$$

$$m = 4 \Rightarrow \sin \theta_4 = 0.800 \Rightarrow \theta_4 = 53.1^\circ$$

$$m = 5 \Rightarrow \sin \theta_5 = 1.000 \Rightarrow \theta_5 = 90^\circ$$

**(b) Determine all the angles for which interference maxima occur for red light.**

$$\sin \theta = m\lambda/d = m(0.700 \mu\text{m})/(2.00 \mu\text{m}) = m(0.350)$$

$$m = 0 \Rightarrow \sin \theta_0 = 0 \Rightarrow \theta_0 = 0^\circ$$

$$m = 1 \Rightarrow \sin \theta_1 = 0.350 \Rightarrow \theta_1 = 20.5^\circ$$

$$m = 2 \Rightarrow \sin \theta_2 = 0.700 \Rightarrow \theta_2 = 44.4^\circ$$

$$m = 3 \Rightarrow \sin \theta_3 = 1.050 \text{ which is impossible}$$

**(c) Over what range of angles are the first, second, etc. orders of the spectrum found?**

First order:  $11.5^\circ$  to  $20.5^\circ$

Second order:  $23.6^\circ$  to  $44.4^\circ$

Third order (partial) begins at  $36.9^\circ$

Fourth order (partial) begins at  $53.1^\circ$

**(d) Which orders are complete (i.e., have angles less than  $90^\circ$  for all wavelengths)?**

Only the first and second orders are complete.

**(e) Which orders are completely separate, and do not overlap with any other orders?**

Only the first order is completely separate. The second order overlaps with the partial third order spectrum.

---

**2. A diffraction pattern for monochromatic light of wavelength  $\lambda = 500 \text{ nm}$  is observed from a single slit of width  $a = 0.08 \text{ mm}$ . How would the pattern be affected by:**

**Doubling the slit width:** The pattern will tighten up (narrow).

**Halving the slit width:** The pattern will spread out.

**Changing the light to blue light:**  $\lambda$  is smaller so the pattern will tighten up (narrow).

**Changing the light to red light:**  $\lambda$  is larger so the pattern will spread out.

**3. It is generally considered undesirable to “close down” a camera lens to a very small aperture, because the quality of the picture is adversely affected. Why?**

Too small an opening leads to a lot of diffraction of the light passing through the lens opening, and this degrades the image.

**4. What is the angle corresponding to the first diffraction minimum for sounds of human speech (say 1000 Hz) passing through a doorway 1.0 m wide?**

We can use  $\sin \theta = \lambda/a$  using the wavelength of the sound ( $\lambda = \frac{v}{f} = \frac{340 \text{ m/s}}{1000 \text{ Hz}} = 0.34 \text{ m}$ )

to find  $\sin \theta = \frac{0.34 \text{ m}}{1.00 \text{ m}} = 0.34$ , or  $\theta = 19.9^\circ$ .

**Express in words the meaning of your result.**

Since the diffraction angle is large, it is clear that it is not necessary to be directly on the other side of the door to hear the sounds; they will easily diffract out at large angles. Of course, they also reflect around easily.