2. **Numerical Problem: Refraction**

You should have found refractive indices for the semiconductors between 3 and 4. Anything in that range will be considered correct.

Additionally, you should have found that \( n(\text{InGaAs}) > n(\text{InP}) \) since InGaAs has a smaller bandgap. This is important because the larger index of InGaAs is how InGaAs /InP lasers confine their optical modes. Furthermore, there would be no critical angle if InGaAs did not have the larger index.

**Angle of Refraction:** If your code should output a plot with the angle of incidence on the x-axis and the angle of refraction on the y-axis – similar to those below.

**Critical Angles:** Your code should produce answers similar to the ones below

- Germanium-Air: \(~14\) degrees
- InGaAs-InP: \(~60 – 70\) degrees
- Fiber Core-Clad: \(80.5\) degrees
3. Numerical Problem: Diffraction

General Procedure:

- Divide the screen into several (~1000 or more) points
- Divide the aperture into N point sources
- For each point on the screen, find the electric field amplitude (Loop 1)
  - Find the path length difference between the first point source and each subsequent point source (Loop 2)
  - Convert each path length difference into a phase shift
  - Add the cosine of half of each phase shift to the field amplitude
- Find the intensity by squaring the field amplitude
- Normalize the intensity by dividing it by its maximum value
- Plot your results
- Alter the incident wavelength and number of point sources to answer the questions

Details of each step are explained in the comments of the code provided below

a) You can calculate the expected minima with the following formula:

\[
\sin(\theta_m) = m\lambda/a \quad y_m = Ltan(\theta_m) \quad m = \text{any integer}
\]

These minima are plotted in red below. Fortunately, they match the numerical calculations.
b) In the code provided below, the Fraunhoffer formula is used to analytically compute the diffraction pattern, which is merely used as a comparison to the numerical model described above. Showing the Fraunhoffer results is not a requirement of the assignment. Keep in mind, if you only used the Fraunhoffer formula and did not use a numerical model, then you cannot answer this question. The Fraunhoffer formula is essentially the result of using an infinite number of point sources (i.e. a line source).

By starting with N=1, you should notice that the numerical model correctly computes the first order of minima, but the rest are wrong. As you add point sources, the higher order minima can be more accurately approximated. I found that between N=20 and N = 50 was enough to approximate the second order minima. Whichever N you chose will be considered correct if your data supports your conclusion.

\[ N = 1 \quad N = 5 \]

\[ N = 20 \quad N = 50 \]
c) With a wavelength of 20 \( \mu \text{m} \), most of the light is transmitted in a near uniform pattern, with maximum brightness in the center of the screen. The bright intensity at the center is consistent with ray optics, but the region of uniform intensity extends to infinity, which is clearly a non-physical prediction. Keep in mind that we assumed paraxial rays when determining the phase shift, so if the intensity fails to approach zero at large angles, the approximation breaks down.

\[ \lambda = 20 \ \mu \text{m} \]

You should observe that the longer wavelength has an intensity pattern with a broader central maximum and fewer orders of minima. The shorter wavelength has a narrower central maximum with more orders of minima. Furthermore, the one half reduction in wavelength results in twice as many minima (if you count infinity as a null).
With longer wavelengths, the slit now has sub-wavelength dimensions, which results in an intensity pattern without any fringes. Without identifying any minima in the intensity pattern, one cannot determine the slit size. To easily determine the size of the slit from the interference pattern, light with a shorter wavelength must be used (in fact, light with a considerably shorter wavelength will work, so long as the Fresnel number is much less than one).