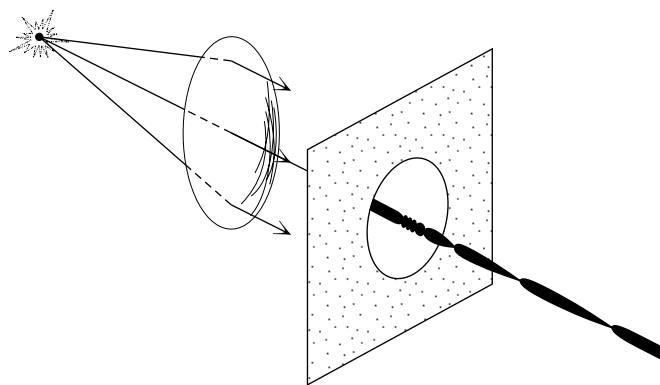


# FRESNEL DIFFRACTION



## FRESNEL DIFFRACTION

by  
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Title: **Fresnel Diffraction**

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Version: 2/1/2000

Evaluation: Stage B0

Length: 1 hr; 12 pages

**Input Skills:**

1. Vocabulary: circular aperture, diffraction, diffraction pattern, Fraunhofer diffraction, Huygen's principle, wavefront (MISN-0-235).
2. Derive the condition for zero intensity for Fraunhofer diffraction by a slit (MISN-0-235).

**Output Skills (Knowledge):**

- K1. Vocabulary: Fresnel diffraction, Fresnel zones.
- K2. Explain how Fresnel diffraction is different from Fraunhofer diffraction.
- K3. Derive the expressions for (i) the phase difference between waves from successive Fresnel zones, (ii) the amplitude of wave motion at an axial point P, and (iii) the radius of the nth Fresnel zone. Draw a sketch showing the Fresnel zones to illustrate your derivations.

**Output Skills (Problem Solving):**

- S1. Given the wavelength of light incident upon a circular aperture of given radius, find the location of the points of maximum and minimum intensity along the axial line through the center of the aperture, for distances close to the aperture. Explain why these locations are points of maximum and minimum intensity.
- S2. For given points along the axial line, find the amplitude of the light arriving at these points relative to the amplitude of the incident wavefront.

**External Resources (Required):**

1. Textbook: M. Alonso and E. J. Finn, *Physics*, Addison-Wesley (1970). For access, see this module's *Local Guide*.

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### 1. Introduction

The diffraction pattern that you observe when monochromatic light passes through a single narrow slit can be analyzed via Huygens' construction not only for the case where the detector (screen) is very far from the slit source (Fraunhofer diffraction), but also for the case where the detector is close to the source (Fresnel diffraction patterns). This module deals with the latter case, introducing the technique of Fresnel zones.

### 2. Fresnel Zone Topics

**2b. Definition.**

**2c. Phase Difference Between Successive Zones.**

**2d. Amplitude Produced at a Point.**

**2d. Radius of the  $n$ -th Zone.**

### 3. Fresnel Diffraction Topics

**3b. Circular Aperture in Opaque Screen.**

**3c. Circular Disc.**

**3c. Intensity Distribution of Fresnel Pattern.**

### 4. Suggestions for Study

1. For Sections 2 and 3, listed above, read AF,<sup>1</sup> Section 29.7, and work through the development in this section. Work through worked out Example 29.4 (p. 710). Work problems 29.20, 29.21, 29.22, 29.23.

<sup>1</sup>M. Alonso and E. J. Finn, *Physics*, Addison-Wesley (1970). For access, see this module's *Local Guide*.

## 5. Comments on Problems, Answers

29.20: Refer to figures 29.22 and 29.23.

a. Radius = 0.77 mm.

b. 1.55 mm is the radius.

What is observed at point  $P$  under each of these conditions?

29.21: When they say "a point is placed..." they presumably mean a "point detector of light intensity is placed..." What is the light intensity (in terms of  $A_0$ ,  $A_1$ , ... of Eq. 29.12) arriving at  $P$  from this circular opening? Answer for radius of aperture:  $2.23 \times 10^{-4}$  m.

29.22: Center will be bright because light from 3 Fresnel zones (and a smidgen more) will arrive there. To get a darkening at the center of the pattern you need to move in toward aperture to 0.75 m from aperture or away from aperture to 1.50 m.

29.23: (a) Points of maximum intensity occur at  $8/n$  meters from the aperture where  $n$  is odd. Points of minimum intensity occur when  $n$  is even; (b) 4 meters.

## Acknowledgments

Preparation of this module was supported in part by the National Science Foundation, Division of Science Education Development and Research, through Grant #SED 74-20088 to Michigan State University.

## LOCAL GUIDE

The readings for this unit are on reserve for you in the Physics-Astronomy Library, Room 230 in the Physics-Astronomy Building. Ask for them as “The readings for CBI Unit 236.” Do **not** ask for them by book title.

## MODEL EXAM

1. These are questions of a general nature about Fresnel diffraction, the answers to which can be found in the text (*Physics*, Alonso and Finn):
  - a. Using one the relations of Table 23.1, show that the phase difference for waves arriving from successive Fresnel zones (in Fig. 29.22) is  $(2\pi/\lambda)(r_{n+1} - r_n)$  where  $r_n, r_{n+1}$  are defined in the figure.
  - b. For this phase difference to be  $\pi$  what must be true about the increment of distance from the edges of the successive zones to  $P$ ?
  - c. What is the radius of the  $n^{\text{th}}$  Fresnel zone that contributes to a point  $P$ , a distance  $r_o$  from the wave front?
  - d. Explain why the amplitude of the resultant wave arriving at point  $P$  from an infinite plane wave whose amplitude is  $\Lambda_0$ , is  $(1/2)\Lambda_0$ .
  - e. If the wave front is blocked by a screen, leaving a circular aperture, then the resulting diffraction pattern arriving at the screen is shown in Fig. 29.24 for various apertures. Explain why the center of the aperture is sometimes bright, sometimes dark. (The center corresponds to point  $P$  of Fig. 29.23)
  - f. Explain how the intensity of the wave arriving at point  $P$  when there is a circular aperture in a screen can be 4 times the intensity when the screen is removed.
  - g. How is Fresnel diffraction different from Fraunhofer diffraction?
2. A plane wave of monochromatic light of wavelength  $\lambda = 5.80 \times 10^{-7}$  meters falls at normal incidence upon a circular aperture of radius  $R = 1.20$  millimeters in an opaque screen. On the other side of the screen, at points on the axis of the circular aperture consider the following:
  - a. How many complete Fresnel zones contribute to the intensity at point 3.70 mm from the center of the aperture? Use a sketch to derive your result; don't just look up a formula. [B]
  - b. At what distance from the center of the aperture does the aperture appear to be one complete Fresnel zone? [D]
  - c. At which point on the axis will you detect the highest intensity of light? [A]

- d. Find the points on the axis where dark spots are to be found. Which is the farthest? [C]

**Brief Answers:**

- A. 2.48 meters from aperture  
B. 671  
C.  $2.48/n$  meters for small  $n$ ,  $n = \text{even integer}$ ; 1.24 meters from aperture.  
D. 2.48 meters

