

Chapter 2.2, Problem 1E
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### Step-by-step solution

**Step 1 of 3**

**Validity of the Fresnel Approximation:**

The validation criterion for a spherical wave to be approximated by a paraboloidal wave within a circle of radius  $a$  and it is originated at a distance  $z$  away from the given axis.

Write the validation condition of the radius of the circle.

$$a^4 \ll 4z^3\lambda \dots\dots (1)$$

Here,  $a$  is the radius of the circle,  $z$  is the distance from the axis and  $\lambda$  is the wavelength.

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**Step 2 of 3**

Calculate the maximum possible radius of the circle.

Substitute  $633 \text{ nm}$  for  $\lambda$  and  $1 \text{ m}$  for  $z$  in equation (1).

$$a^4 \ll 4(1 \text{ m})^3(633 \text{ nm})\left(\frac{10^{-9} \text{ m}}{1 \text{ nm}}\right)$$

$$a \ll 0.0398 \text{ m}$$

Thus, the radius of the circle is  $0.0398 \text{ m}$ .

Write the equation for the maximum angle.

$$\theta_m = \frac{a}{z}$$

Here,  $\theta_m$  is the maximum angle.

Substitute  $0.0398 \text{ m}$  for  $a$  and  $1 \text{ m}$  for  $z$ .

$$\theta_m = \frac{0.0398 \text{ m}}{1 \text{ m}} = 0.0398 \text{ rad}$$

Thus, the required angle is  $0.0398 \text{ rad}$ .

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**Step 3 of 3**

Write the equation for the Fresnel number.

$$N_f = \frac{a^2}{\lambda z}$$

Here,  $N_f$  is the Fresnel number.

Substitute  $0.0398 \text{ m}$  for  $a$ ,  $1 \text{ m}$  for  $z$  and  $633 \text{ nm}$  for  $\lambda$ .

$$N_f = \frac{(0.0398 \text{ m})^2}{(633 \text{ nm})\left(\frac{10^{-9} \text{ m}}{1 \text{ nm}}\right)(1 \text{ m})}$$

$$= 2513.7$$

$$\approx 2514$$

Thus, the Fresnel number is  $2514$ .

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