

## MATHEMATICAL QUESTIONS

### Question 1

In a simple on-off keying digital optical communication system using single-mode thermal light, how many photons are required on average to keep the bit error rate below  $10^{-9}$  in the following conditions?

(a) The receiver can detect one or more photons.

(b) The receiver can detect  $N$  or more photons.

### Question 2

Derive an expression for the Fraunhofer diffraction pattern from a rectangular aperture, of height  $D_y$  and width  $D_x$  observed at a distance  $d$ . Find the half-angular widths of the central lobe of the pattern.

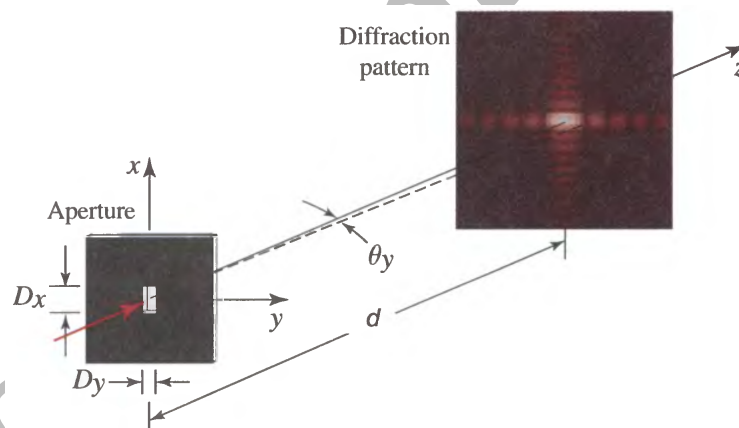


Figure 1: Fraunhofer diffraction pattern from a rectangular aperture.

### Question 3

Derive an expression for the Fraunhofer diffraction pattern from a circular aperture of diameter  $D$  observed at a distance  $d$ . Find the half-angular width of the central lobe of the pattern.

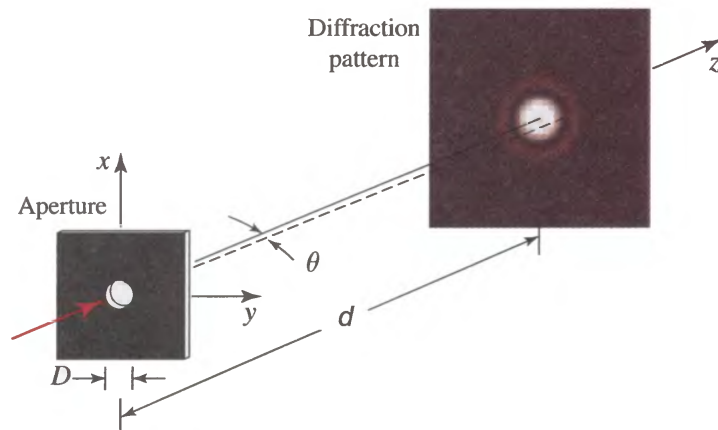


Figure 2: Fraunhofer diffraction pattern from a circular aperture.

#### Question 4

Derive an expression for the Fresnel diffraction pattern from a circular aperture of diameter  $D$  observed at a distance  $d$ . Compare the result with the corresponding Fraunhofer diffraction pattern.

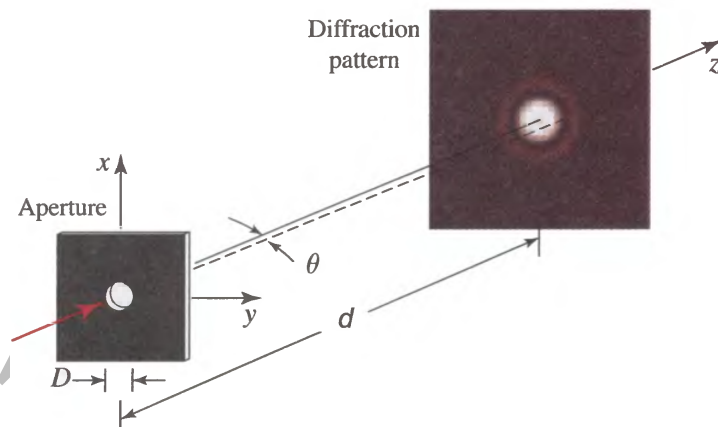


Figure 3: Fresnel diffraction pattern from a circular aperture.

#### Question 5

Show that the Fresnel zone plate with the complex amplitude transmittance

$$f(x, y) = u\left[\cos\left(\pi \frac{x^2 + y^2}{\lambda f}\right)\right]$$

, where  $u(x)$  is the unit step function, acts as a spherical lens with multiple focal lengths at  $f, f/2, f/3, \dots$ .

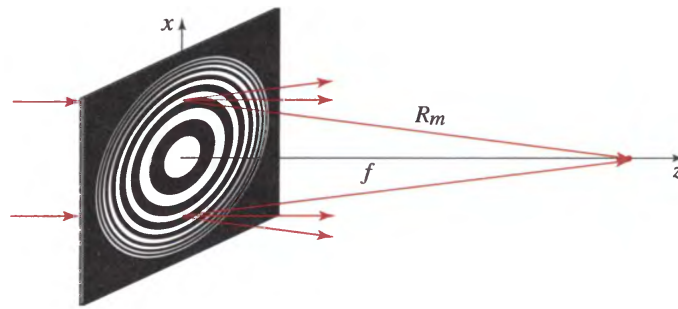


Figure 4: Fresnel zone plate.

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## SOFTWARE QUESTIONS

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### Question 6

Use Python or MATLAB to develop a program that gets the handle of an aperture transmittance function  $p(x, y)$  and plots 3D image of the Huygens, Fresnel, and Fraunhofer diffraction patterns at distance  $d$ .

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## BONUS QUESTIONS

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### Question 7

Create a GUI for your developed program in Question 6 and then, make a standalone application. The GUI may have some fields to receive aperture transmittance function  $p(x, y)$ , distance  $d$ , and pattern type.

### Question 8

Return your answers by filling the  $\text{\LaTeX}$  template of the assignment.