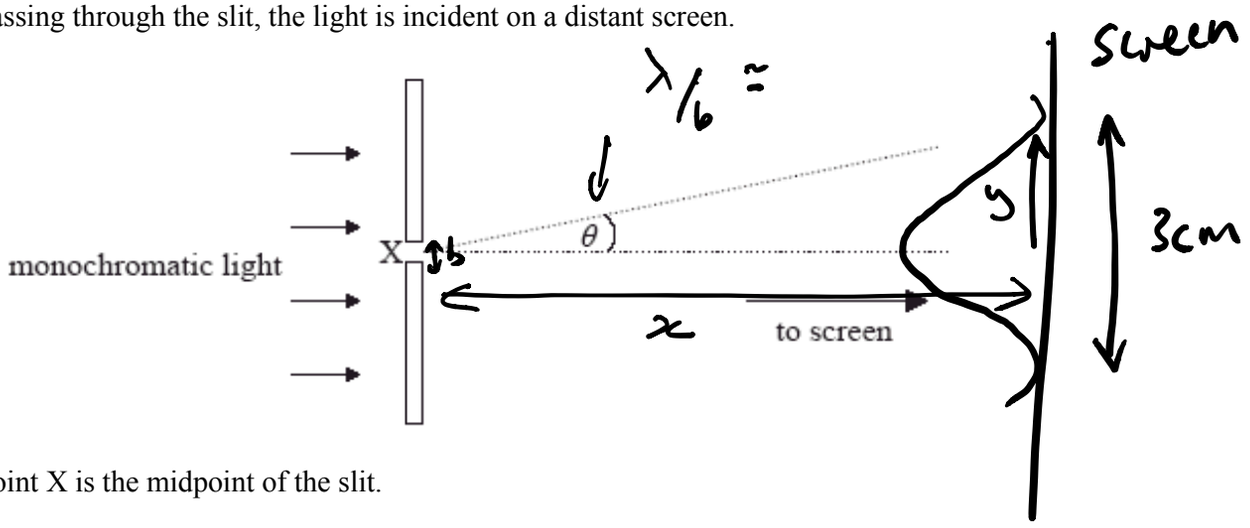
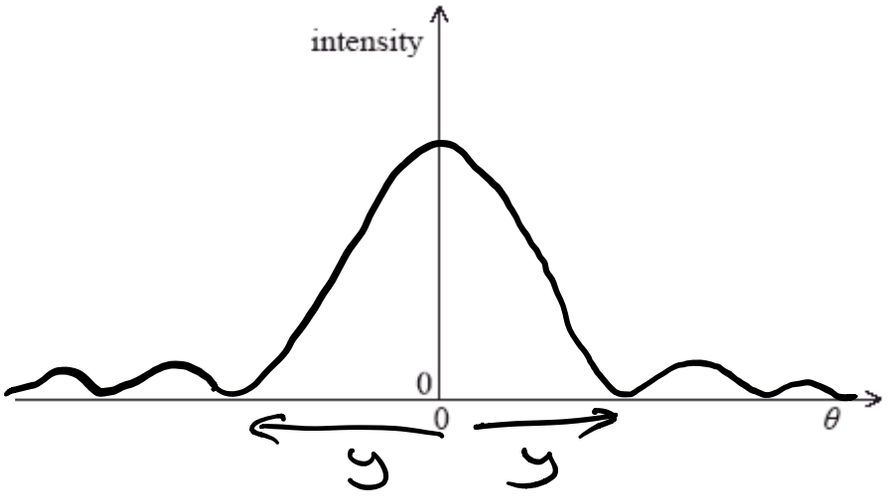
1. This question is about diffraction and resolution.

(a) A parallel beam of monochromatic light is incident on a narrow rectangular slit. After passing through the slit, the light is incident on a distant screen.



Point X is the midpoint of the slit.

(i) On the axes below, sketch a graph to show how the intensity of the light on the screen varies with the angle θ shown in the diagram.



(3)

(ii) The wavelength of the light is 520 nm, the width of the slit is 0.04 mm and the screen is 1.2 m from the slit. Show that the width of the central maximum of intensity on the screen is about 3 cm.

$\frac{\lambda}{b} = \frac{y}{x}$

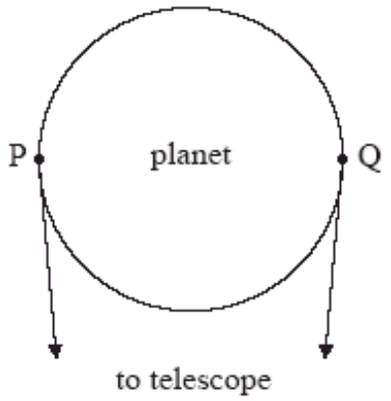
$\frac{520 \times 10^{-9}}{0.04 \times 10^{-3}} = \frac{y}{1.2}$

$y = \frac{(1.2)(520 \times 10^{-9})}{0.04 \times 10^{-3}}$

$2y = 0.03\text{m}$

(2)

(b) Points P and Q are on the circumference of a planet as shown.



By considering the two points, outline why diffraction limits the ability of an astronomical telescope to resolve the image of the planet as a disc.

Both P + Q will be observed as diffraction disks. The size of the disks is dependent on the diameter of the telescope. A smaller diameter will cause the disks to overlap + prevent P & Q to be resolved.

(3)
(Total 8 marks)

A space shuttle orbits at a height of 300 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.
The observer views the panels with a telescope of aperture diameter 85 mm. The panels act as point sources of light for the observer.

(i) Describe what is meant by the Rayleigh criterion. 2 Sources are at the L of R when the central max. of one disk overlaps the first minimum of the other disk.

(ii) Determine whether the images of the panels formed by the telescope will be resolved.

$\theta_{limit} = 1.22\,\lambda/b = \frac{1.22 \times 500 \times 10^{-9}}{85 \times 10^{-3}}$

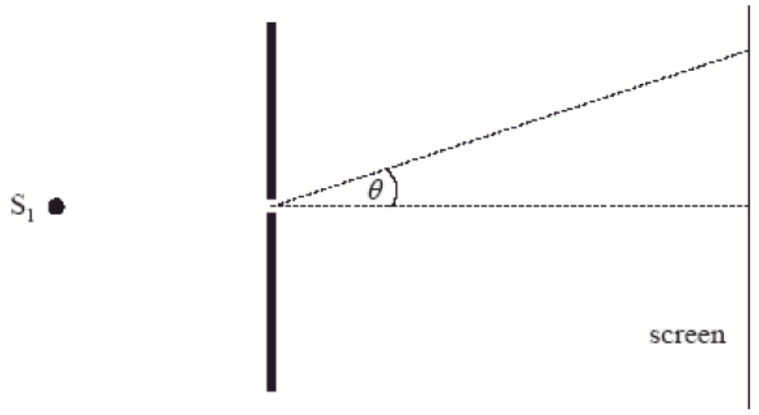
$= 0.000007$1 radians.

$\theta_{separation} = \frac{y}{x} = \frac{24}{300000} = 0.00008$ radians.

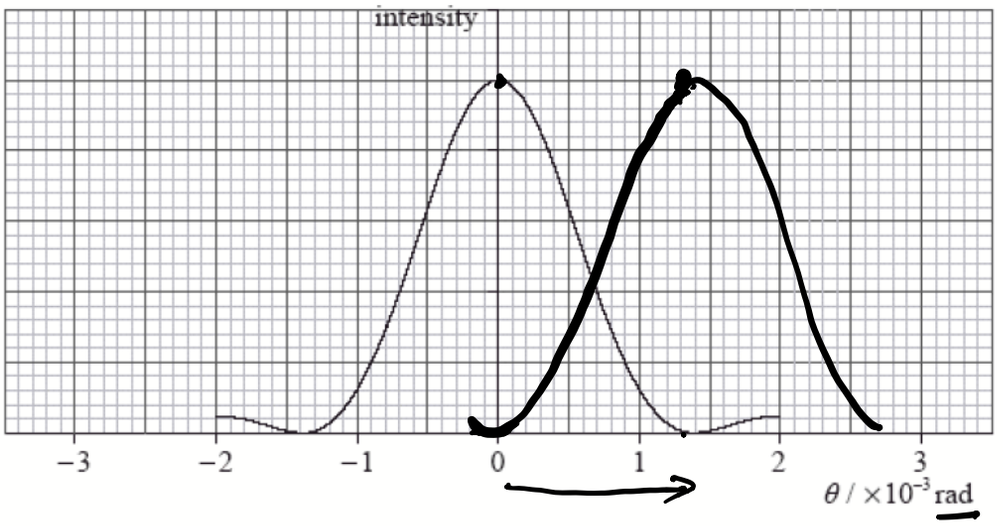
b/c $\theta_{sep.} > \theta_{limit}$ Resolve the panels.

This question is about diffraction and resolution.

(a) Light from a monochromatic point source S_1 is incident on a narrow rectangular slit.



After passing through the slit, the light is incident on a screen some distance away from the slit. The graph shows how the intensity distribution on the screen varies with the angle θ shown in the diagram.

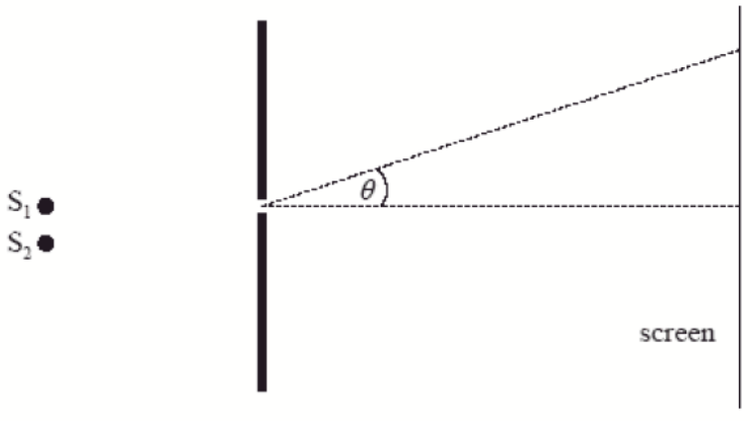


(i) The width of the slit is 4.0×10^{-4} m. Use data from the graph to calculate the wavelength of the light.

$\theta = \frac{\lambda}{b}$ $\lambda = \theta \times b = (1.4 \times 10^{-3})(4 \times 10^{-4})$

$= 5.6 \times 10^{-7}$ m

(ii) An identical source S_2 is placed close to S_1 as shown.



The images of the two sources on the screen are just resolved according to the Rayleigh criterion. On the graph above, draw the intensity distribution of the second source.

(1)

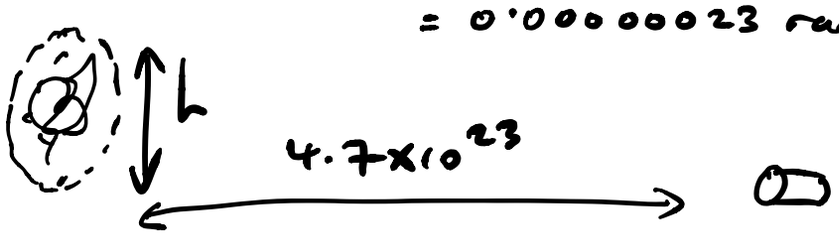
(b) The Very Large Array (VLA) is used to analyse radio signals from distant galaxies. The combined diameter of the VLA is 36 km. A region of linear size L inside the radio galaxy M87 emits radio waves with a frequency of 43 GHz. The galaxy is a distance 4.7×10^{23} m from Earth. The VLA can just resolve the radio emitting region. Estimate the value of L.

$\theta_{limit} = 1.22 \lambda / b$

$= 1.22 (0.007 / 36000)$

$= 0.00000023$ rad.

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{43 \times 10^9}$



$\frac{L}{4.7 \times 10^{23}} = 0.00000023$

$L = 0.00000023 \times 4.7 \times 10^{23}$

$= 1.11 \times 10^{17}$ m.