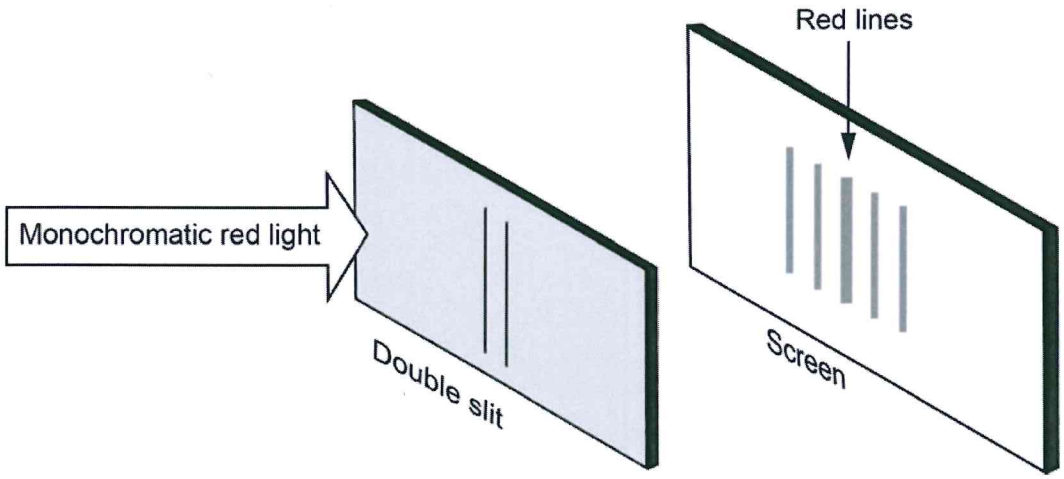
# Question 1

**(3 marks)**

The pattern observed when monochromatic light passes through a piece of cardboard with twin slits close together is often considered evidence for the wave theory of light. A diagram of an experiment set up in a classroom is provided below.




Explain how the pattern of red lines is formed on the screen and why this is considered to be evidence for the wave theory of light.

# Question 2

**(15 marks)**

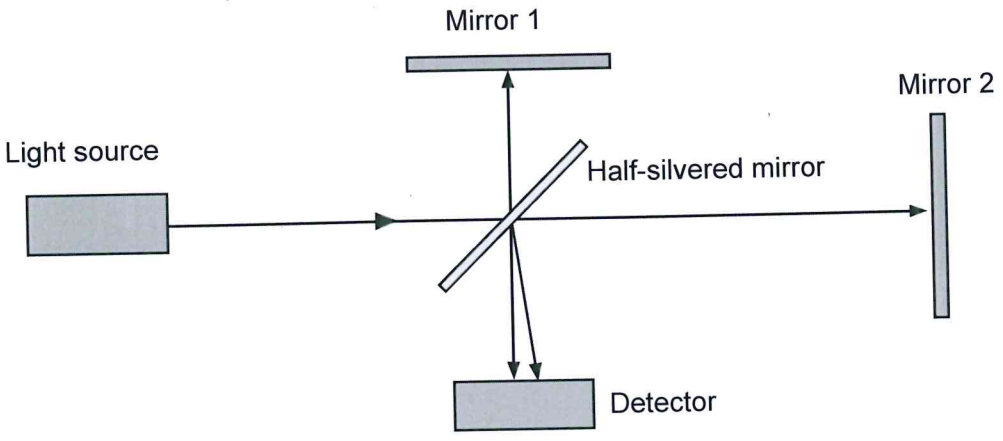
**Radio Telescopes and Interferometry**

Light Interferometry

An interferometer is a device that can split a light beam into two parts and recombine them to form an interference pattern after they have travelled over different paths. A light interferometer can be used to accurately determine wavelengths or distance.

A simplified diagram of an interferometer is shown below. A beam of light is incident on a half-silvered mirror. Some of the light is reflected from this mirror and is incident on Mirror 1. The remaining light is transmitted through the half silvered mirror and is incident on Mirror 2. Light from both mirrors is then reflected back and received at the detector.

An observer at the detector may see an interference pattern consisting of a series of bright and dark lines. The spacing of the lines depends on the distances the two light beams, arriving at the detector, have travelled.



# Question 2 cont

Resolving Power

The resolving power of a telescope is a measure of its ability to distinguish between objects separated by a small angular distance. Point like sources that are separated by an angle smaller than the resolving power of the telescope will not be seen as separate.

The angular resolution of a telescope can be approximated to $R = \frac{57.3 \times \lambda}{D}$

where $\lambda$ is the wavelength of the observed radiation, $D$ is the diameter of the aperture or lens used in the telescope and $R$ is the distance between the objects being observed in degrees.

A way of increasing the resolving power of a telescope is to use interferometry. An array of telescopes arranged in a grid can all look at the same region of the sky. The signals from the telescopes are combined and the interference pattern can be interpreted to determine the exact location of a source in the sky.

The resolution of an array of telescopes can be calculated using $R = \frac{57.3 \times \lambda}{B}$

where B is the distance between telescopes in the array.

The Square Kilometre Array is a radio telescope that will be built in southern Africa and Western Australia. It is thought that both of these regions offer the best opportunity for observing without interference from other radio sources. When it is complete it will have a total collecting area of more than 1 square kilometre and the maximum distance between the central core of receivers and the most distant will be approximately 3000 km.

(a) Explain why a series of dark and light fringes may be observed at the detector of an interferometer. (3 marks)

(b) In an interferometer the distance from the half-silvered mirror to Mirror 1 is 1.5 m. The distance from the half-silvered mirror to Mirror 2 is 1.85 m. The light used in the interferometer has a wavelength of 694 nm. Calculate the difference in path length between the light beams arriving at the detector in terms of number of wavelengths. You should express your answer to 1 significant figure. (2 marks)

(c) Two stars, separated by an angle of 0.5°, are both emitting radio waves with a frequency of $1 \times 10^6$ Hz. Can they be seen as separate sources by a telescope with a diameter of 76 m? You should show the calculations you have used to justify your answer. (4 marks)

(d) Determine the resolution of two telescopes, 5 km apart receiving radio waves with a wavelength of 1.71 m. (2 marks)

(e) Give **three (3)** reasons why radio waves are used to explore very distant regions of the Universe instead of visible light by comparing the characteristics of the two regions of the electromagnetic spectrum. (4 marks)