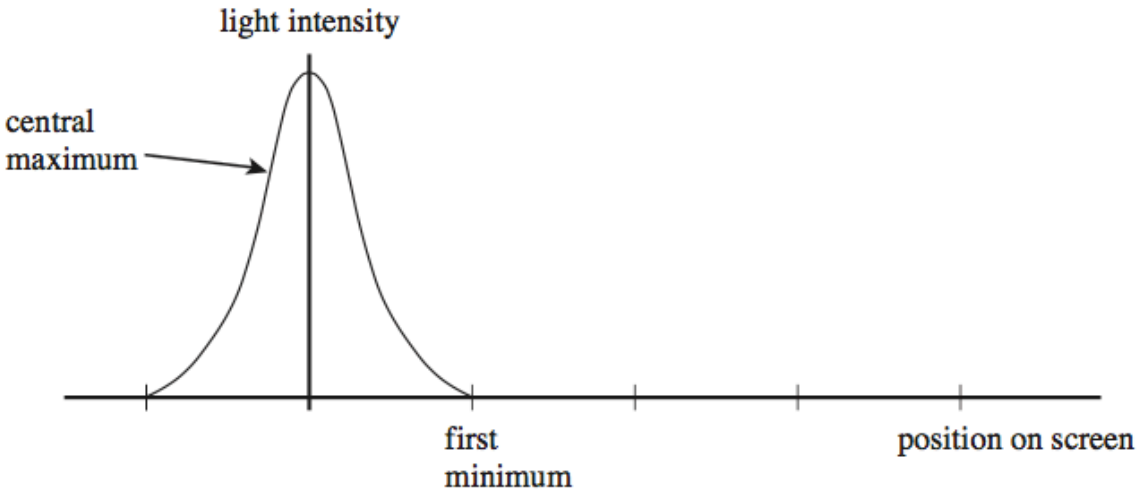
1)

A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in **Figure 3**.

Figure 3



(a) On **Figure 3**, sketch how the intensity varies across the screen to the right of the central maximum.

(2 marks)

(b) A laser is a source of *monochromatic*, *coherent* light. State what is meant by

monochromatic light .....

.....

coherent light .....

.....

(2 marks)

(c) Describe how the pattern would change if light of a longer wavelength was used.

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(1 mark)

(d) State **two** ways in which the appearance of the fringes would change if the slit was made narrower.

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(2 marks)

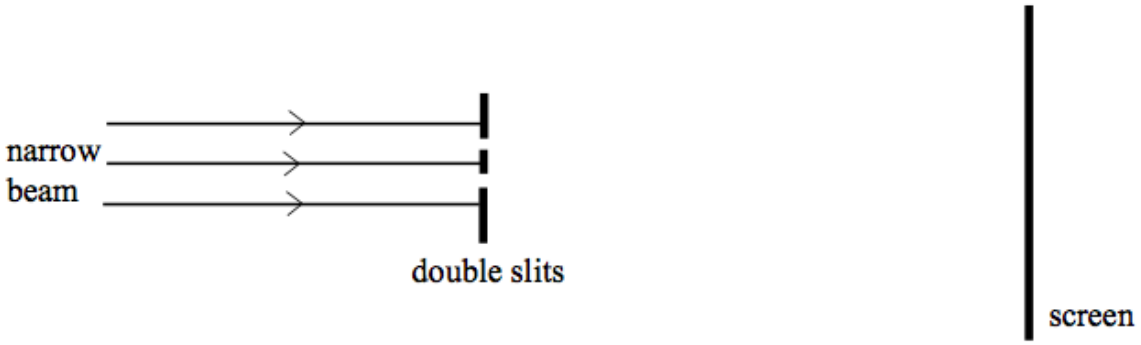
(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

(3 marks)

2)

A narrow beam of monochromatic red light is directed at a double slit arrangement. Parallel red and dark fringes are seen on the screen shown in **Figure 7**.

Figure 7



(a) (i) Light passing through each slit spreads out. What is the name for this effect?

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(1 mark)

(a) (ii) Explain the formation of the fringes seen on the screen.

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(4 marks)

(a) (iii) The slit spacing was 0.56 mm. The distance across 4 fringe spacings was 3.6 mm when the screen was at a distance of 0.80 m from the slits. Calculate the wavelength of the red light.

Answer ..... m

(4 marks)

(b) Describe how the appearance of the fringes would differ if white light had been used instead of red light.

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(3 marks)

3)

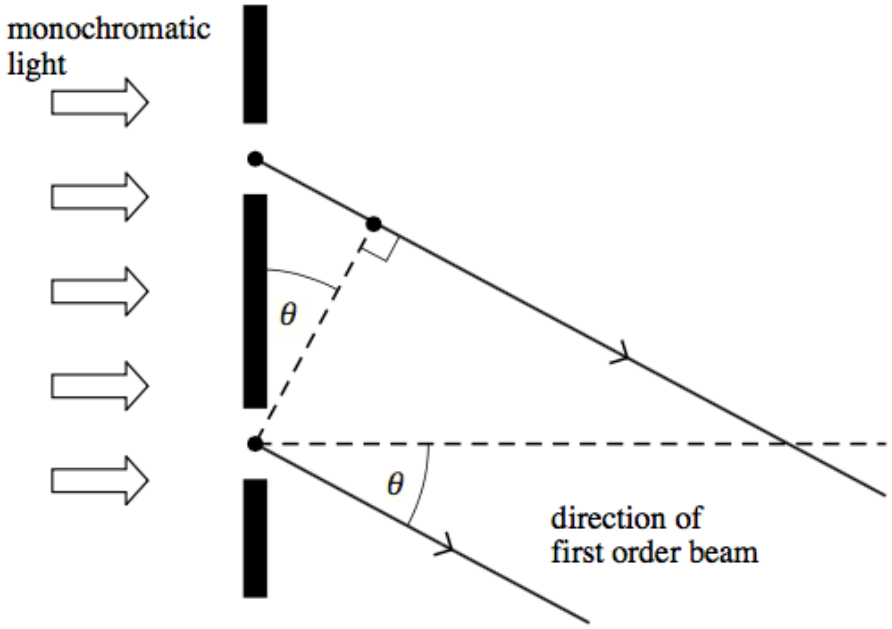
For a plane transmission diffraction grating, the diffraction grating equation for the first order beam is:

$$\lambda = d \sin \theta$$

(a) **Figure 6** shows two of the slits in the grating. Label **Figure 6** with the distances d and λ.

(2 marks)

Figure 6



(b) State and explain what happens to the value of angle θ for the first order beam if the wavelength of the monochromatic light decreases.

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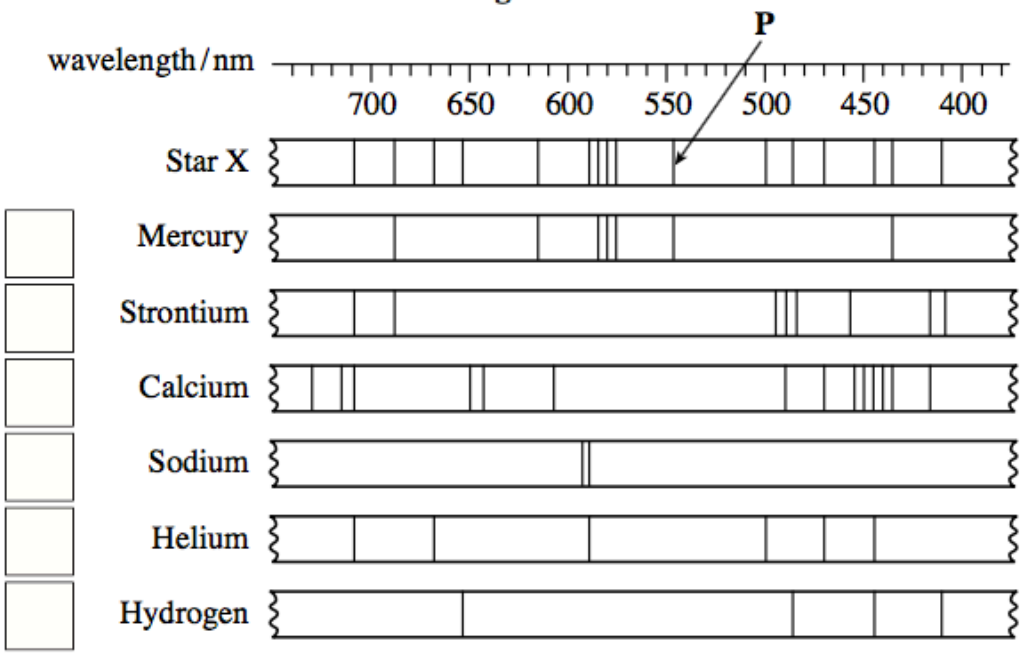
(2 marks)

(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star X shown in **Figure 7**. Below this are some line spectra for six elements that have been obtained in the laboratory.

Place ticks in the boxes next to the **three** elements that are present in the atmosphere of star X.

(2 marks)

Figure 7



(d) The diffraction grating used to obtain the spectrum of star X had 300 slits per mm.

(d) (i) Calculate the distance between the centres of two adjacent slits on this grating.

answer = ... m

(1 mark)

(d) (ii) Calculate the first order angle of diffraction of line **P** in **Figure 7**.

answer = ... degrees

(2 marks)

4)

Just over two hundred years ago Thomas Young demonstrated the interference of light by illuminating two closely spaced narrow slits with light from a single light source.

(a) What did this suggest to Young about the nature of light?

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.....

(1 mark)

(b) The demonstration can be carried out more conveniently with a laser. A laser produces *coherent*, *monochromatic* light.

(b) (i) State what is meant by monochromatic.

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(b) (ii) State what is meant by coherent.

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.....

(2 marks)

(b) (iii) State **one** safety precaution that should be taken while using a laser.

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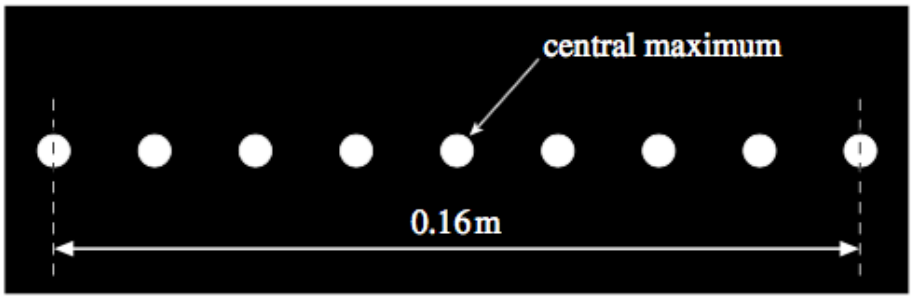
(1 mark)

(c) **Figure 6** shows the maxima of a two slit interference pattern produced on a screen when a laser was used as a monochromatic light source.

Figure 6



The slit spacing = 0.30 mm.
The distance from the slits to the screen = 10.0 m.

Use **Figure 6** to calculate the wavelength of the light that produced the pattern.

answer = ... m

(3 marks)

(d) The laser is replaced by another laser emitting visible light with a shorter wavelength. State and explain how this will affect the spacing of the maxima on the screen.

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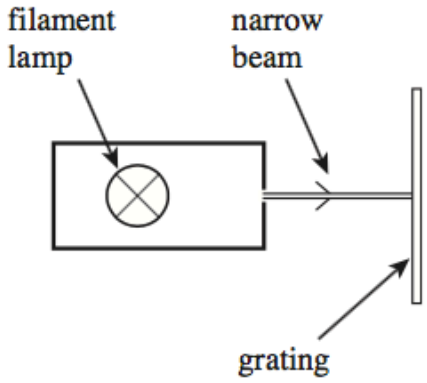
(2 marks)

5)

(a) In an experiment, a narrow beam of white light from a filament lamp is directed at normal incidence at a diffraction grating. Complete the diagram in **Figure 5** to show the light beams transmitted by the grating, showing the zero-order beam and the first-order beams.

Figure 5



(3 marks)

(b) Light from a star is passed through the grating.

Explain how the appearance of the first-order beam can be used to deduce **one** piece of information about the gases that make up the outer layers of the star.

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(2 marks)

(c) In an experiment, a laser is used with a diffraction grating of known number of lines per mm to measure the wavelength of the laser light.

(c) (i) Draw a labelled diagram of a suitable arrangement to carry out this experiment.

(2 marks)

(c) (ii) Describe the necessary procedure in order to obtain an accurate and reliable value for the wavelength of the laser light.
Your answer should include details of all the measurements and necessary calculations.
The quality of your written communication will be assessed in your answer.

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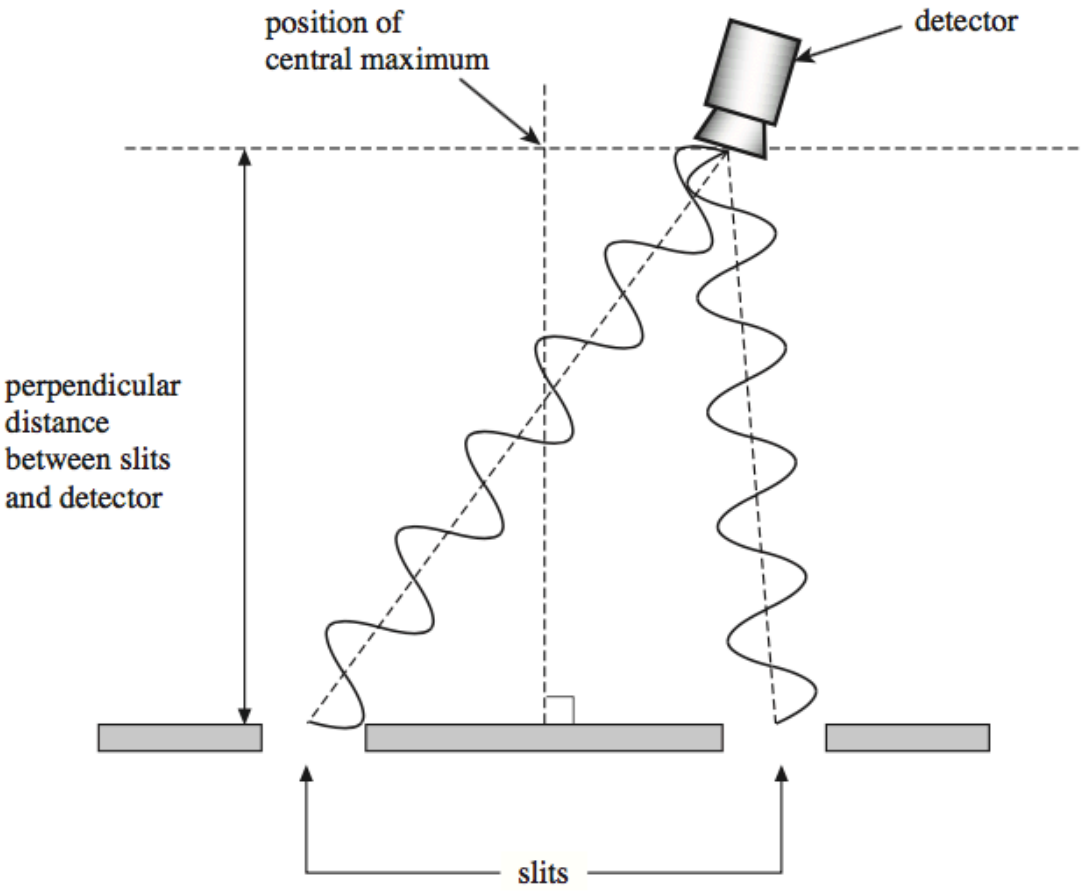
(6 marks)

6)

Figure 5 shows the paths of microwaves from two narrow slits, acting as coherent sources, through a vacuum to a detector.

Figure 5



(a) Explain what is meant by *coherent sources*.

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(2 marks)

(b) (i) The frequency of the microwaves is 9.4 GHz.

Calculate the wavelength of the waves.

wavelength = ... m

(2 marks)

(b) (ii) Using **Figure 5** and your answer to part **(b)(i)**, calculate the path difference between the two waves arriving at the detector.

path difference = ... m

(1 mark)

(c) State and explain whether a maximum or minimum is detected at the position shown in **Figure 5**.

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(3 marks)

(d) The experiment is now rearranged so that the perpendicular distance from the slits to the detector is 0.42 m. The interference fringe spacing changes to 0.11 m.

Calculate the slit separation. Give your answer to an appropriate number of significant figures.

slit separation = ... m

(3 marks)

(e) With the detector at the position of a maximum, the frequency of the microwaves is now doubled. State and explain what would now be detected by the detector in the same position.

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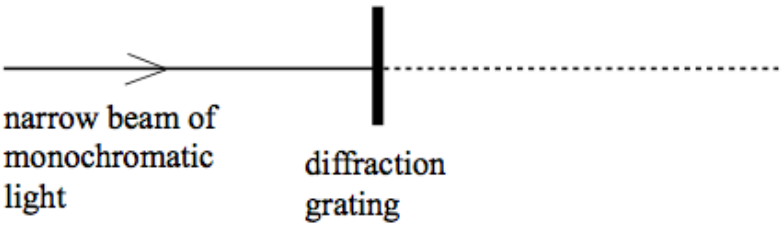
(3 marks)

7)

A narrow beam of monochromatic light of wavelength 590 nm is directed normally at a diffraction grating, as shown in **Figure 8**.

Figure 8



(a) The grating spacing of the diffraction grating is 1.67×10^{-6} m.

(a) (i) Calculate the angle of diffraction of the second order diffracted beam.

answer.....degrees
(4 marks)

(a) (ii) Show that no beams higher than the second order can be observed at this wavelength.

(3 marks)

(b) The light source is replaced by a monochromatic light source of unknown wavelength. A narrow beam of light from this light source is directed normally at the grating. Measurement of the angle of diffraction of the second order beam gives a value of 42.1°.

Calculate the wavelength of this light source.

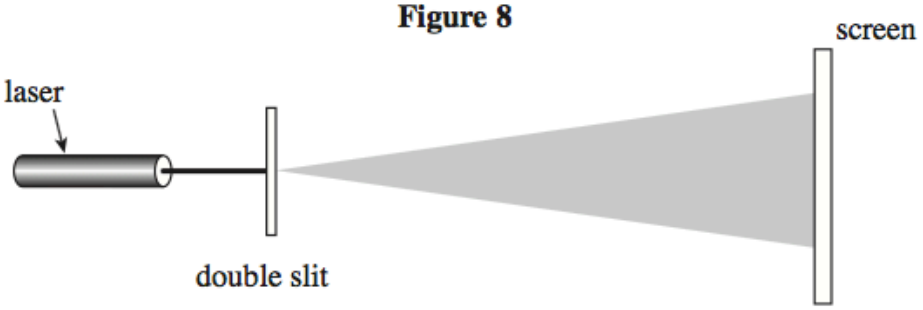
answer.....m

(2 marks)

8)

A scientist is going to use a double-slit arrangement to carry out measurements in order to determine the wavelength of light from a laser.

Figure 8



(a) The scientist has a double slit of known separation. Describe the measurements that need to be taken and explain how they are used to find the wavelength of the light. Discuss any necessary safety precautions and how you would arrange the apparatus to improve accuracy.

The quality of your written communication will be assessed in this question.

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(6 marks)

(b) In 1802 Thomas Young used candle light to observe the interference pattern from two narrow slits acting as *coherent light sources*.

Explain what is meant by coherent light sources.

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(2 marks)

(c) Sketch and label on the diagram below the arrangement that Young would have used to obtain his interference pattern.

(2 marks)

(d) State **two** differences in the appearance of the pattern obtained with a laser and that produced by a white light source such as a candle.

Difference 1 .....

.....

Difference 2 .....

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(2 marks)

(e) Explain how the wave theory of light accounts for the areas on the screen where the intensity is a minimum.

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(2 marks)

9)

Figure 6 shows a spectrometer that uses a diffraction grating to split a beam of light into its constituent wavelengths and enables the angles of the diffracted beams to be measured.

(a) Give **one** possible application of the spectrometer and diffraction grating used in this way.

[1 mark]

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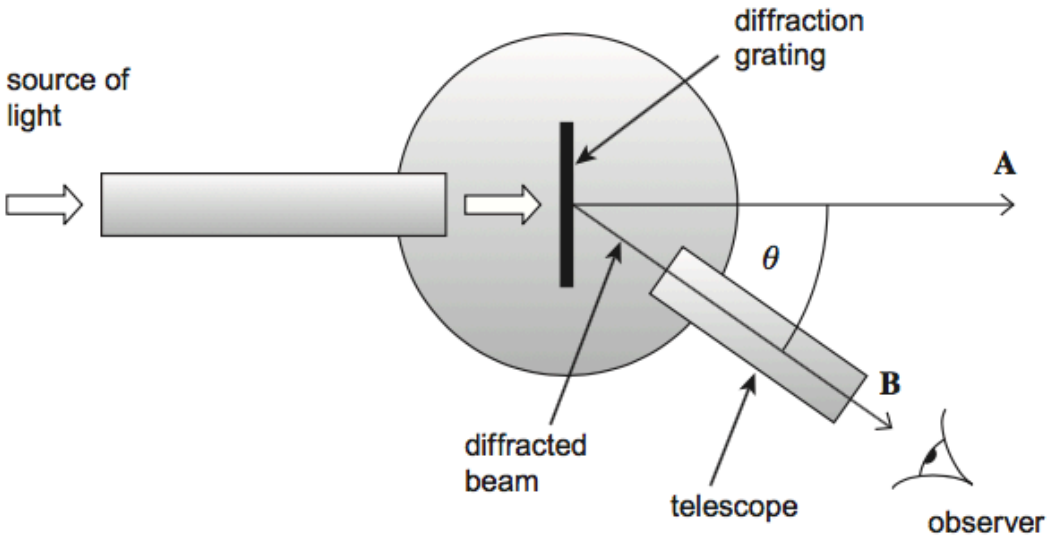
Figure 6



(b) (i) When the spectrometer telescope is rotated from an initial angle of zero degrees, a spectrum is not observed until the angle of diffraction θ is about 50°. State the order of this spectrum.

[1 mark]

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(b) (ii) White light is directed into the spectrometer. Light emerges at **A** and **B**. State **one** difference between the light emerging at **B** compared to that emerging at **A**.

[1 mark]

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(c) The angle of diffraction θ at the centre of the observed beam **B** in **Figure 6** is 51.0° and the grating has 1480 lines per mm.

Calculate the wavelength of the light observed at the centre of beam **B**.

[3 marks]

wavelength ..... m

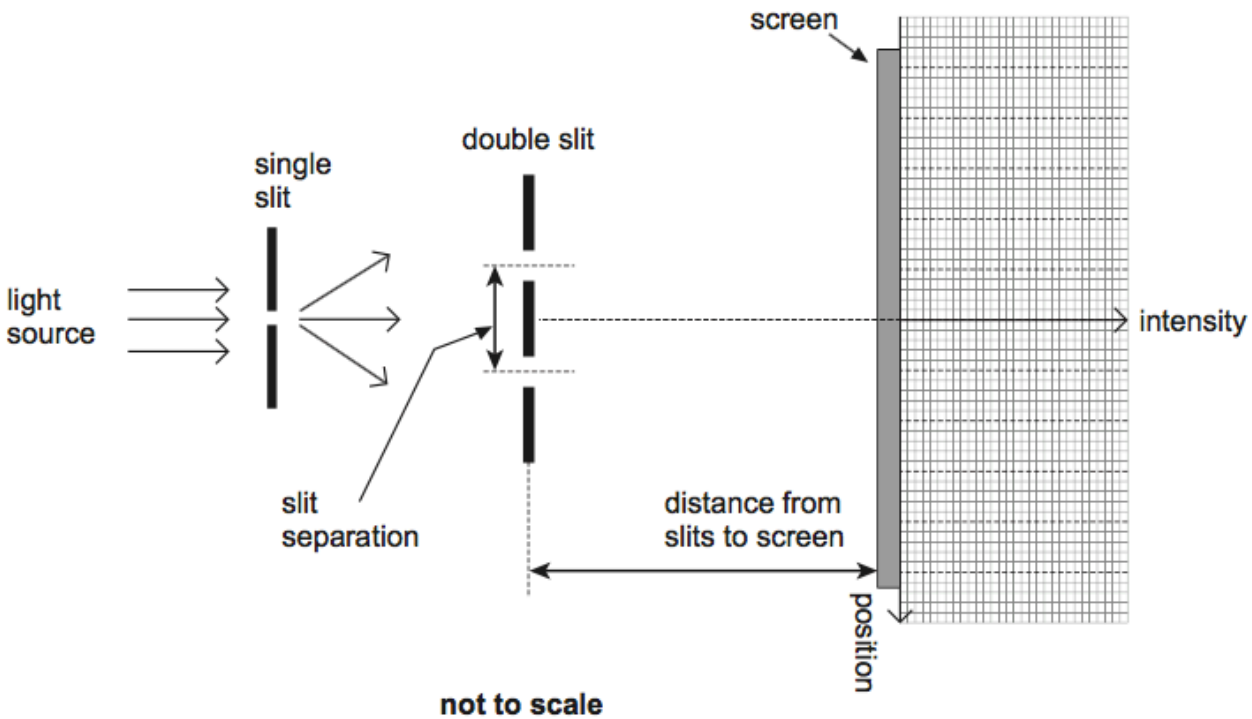
(d) Determine by calculation whether any more orders could be observed at the wavelength calculated in part (c).

[2 marks]

10)

Figure 7 shows Young's double-slit experiment performed with a tungsten filament lamp as the light source.

Figure 7



not to scale

(a) On the axes in **Figure 7**, sketch a graph to show how the intensity varies with position for a **monochromatic** light source.

[2 marks]

(b) (i) For an interference pattern to be observed the light has to be emitted by two **coherent sources**.
Explain what is meant by coherent sources.

[1 mark]

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(b) (ii) Explain how the use of the single slit in the arrangement in **Figure 7** makes the light from the two slits sufficiently coherent for fringes to be observed.

[1 mark]

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(b) (iii) In this experiment light behaves as a wave.
Explain how the bright fringes are formed.

[3 marks]

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(c) (i) A scientist carries out the Young double-slit experiment using a laser that emits violet light of wavelength 405 nm. The separation of the slits is 5.00×10^{-5} m.

Using a metre ruler the scientist measures the separation of two adjacent bright fringes in the central region of the pattern to be 4 mm.

Calculate the distance between the double slits and the screen.

[2 marks]

distance = ... m

(c) State and explain **one** precaution that should be taken when using laser light.

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(2 marks)

(d) The red laser light is replaced by a non-laser source emitting white light.

Describe how the appearance of the pattern would change.

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(3 marks)

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11)

(a) A laser emits *monochromatic light*.

Explain the meaning of the term monochromatic light.

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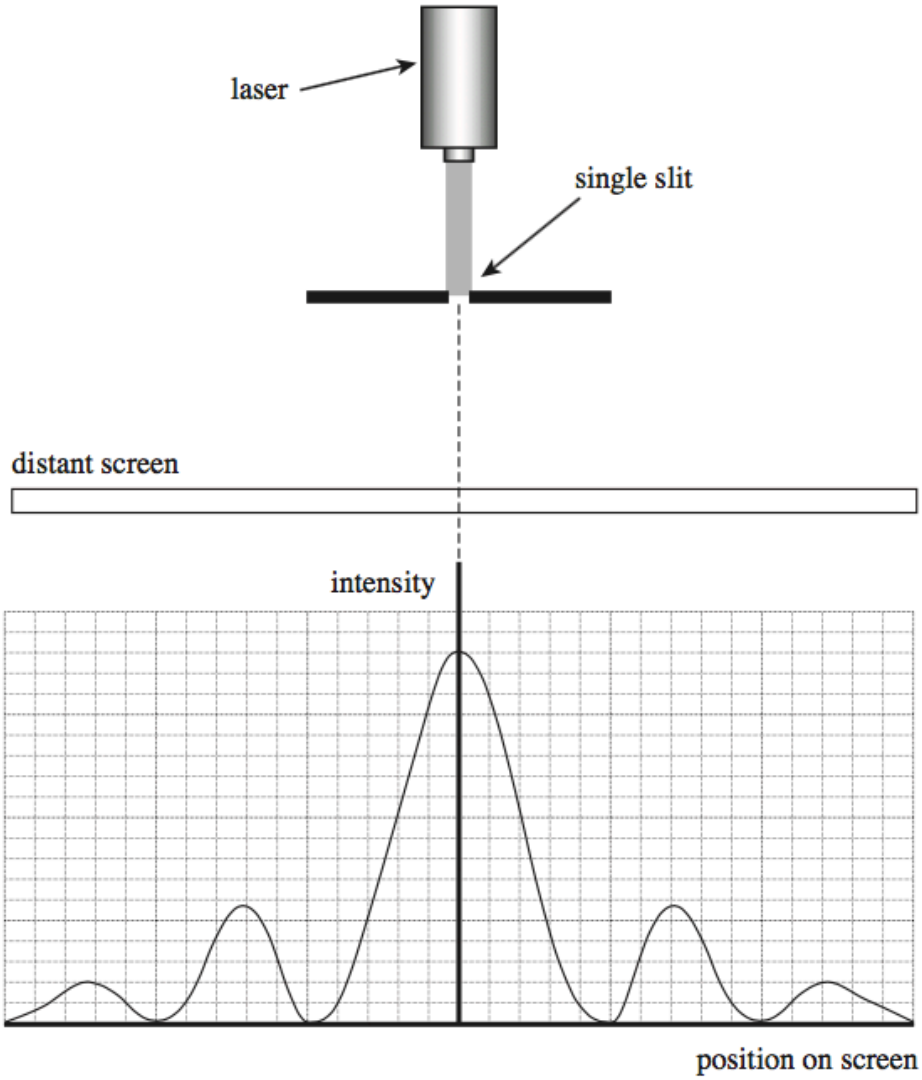
(1 mark)

(b) **Figure 9** shows a laser emitting blue light directed at a single slit, where the slit width is greater than the wavelength of the light. The intensity graph for the diffracted blue light is shown.

Figure 9



The laser is replaced by a laser emitting red light.

(b) On the axes shown in **Figure 9**, sketch the intensity graph for a laser emitting red light.

(2 marks)