Q1. Electrons and protons in two beams are travelling at the same speed. The beams are diffracted by objects of the same size.

Which correctly compares the de Broglie wavelength λ_e of the electrons with the de Broglie wavelength λ_p of the protons and the width of the diffraction patterns that are produced by these beams?

	comparison of de Broglie wavelength	diffraction pattern	
A	$\lambda_e > \lambda_p$	electron beam width > proton beam width	☐
B	$\lambda_e < \lambda_p$	electron beam width > proton beam width	☐
C	$\lambda_e > \lambda_p$	electron beam width < proton beam width	☐
D	$\lambda_e < \lambda_p$	electron beam width < proton beam width	☐

(Total 1 mark)

Q2. A diffraction pattern is formed by passing monochromatic light through a single slit. If the width of the single slit is reduced, which of the following is true?

	Width of central maximum	**Intensity of central maximum**	
A	unchanged	decreases	☐
B	increases	increases	☐
C	increases	decreases	☐
D	decreases	decreases	☐

(Total 1 mark)

Q3. Read through the following passage and answer the questions that follow it.

Measuring the speed of sound in air

After the wave nature of sound had been identified, many attempts were made to measure its speed in air. The earliest known attempt was made by the French scientist Gassendi in the 17th century. The procedure involved timing the interval between seeing the flash of a gun and hearing the bang from some distance away. Gassendi assumed that, compared with the speed of sound, the speed of light is infinite. The value he obtained for the speed of sound was 480 m s^{-1}. He also realised that the speed of sound does not depend on frequency.
A much better value of 350 m s^{-1} was obtained by the Italian physicists Borelli and Viviani using the same procedure. In 1740 another Italian, Bianconi, showed that sound travels faster when the temperature of the air is greater.
In 1738 a value of 332 m s^{-1} was obtained by scientists in Paris. This is remarkably close to the currently accepted value considering the measuring equipment available to the scientists at that time. Since 1986 the accepted value has been 331.29 m s^{-1} at 0 °C.

(a) Suggest an experiment that will demonstrate the wave nature of sound (line 1).

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(1)

(b) Using Gassendi's value for the speed of sound (line 6), calculate the time between seeing the flash of a gun and hearing its bang over a distance of 2.5 km.

time = ... s

(1)

(c) Explain why it was necessary to assume that 'compared with the speed of sound, the speed of light is infinite' (line 5).

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(1)

(d) Explain **one** observation that could have led Gassendi to conclude that 'the speed of sound does not depend on frequency' (line 7).

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(2)

(e) Explain how the value obtained by Borelli and Viviani was 'much better' than that obtained by Gassendi (line 8).

....

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(1)

(f) The speed of sound c in dry air is given by

$$c = k\sqrt{\theta + 273.15}$$

where θ is the temperature in °C, and k is a constant.

Calculate a value for k using data from the passage.

k = ... m s^{-1} $K^{-½}$

(2)

(g) State the steps taken by the scientific community for the value of a quantity to be 'accepted' (line 13).

....

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(2)
(Total 10 marks)

Q4. When comparing X-rays with UV radiation, which statement is correct?

A	X-rays have a lower frequency.	⬭
B	X-rays travel faster in a vacuum.	⬭
C	X-rays do not show diffraction and interference effects.	⬭
D	Using the same element, photoelectrons emitted using X-rays have the greater maximum kinetic energy.	⬭

(Total 1 mark)

Q5. The figure below 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.

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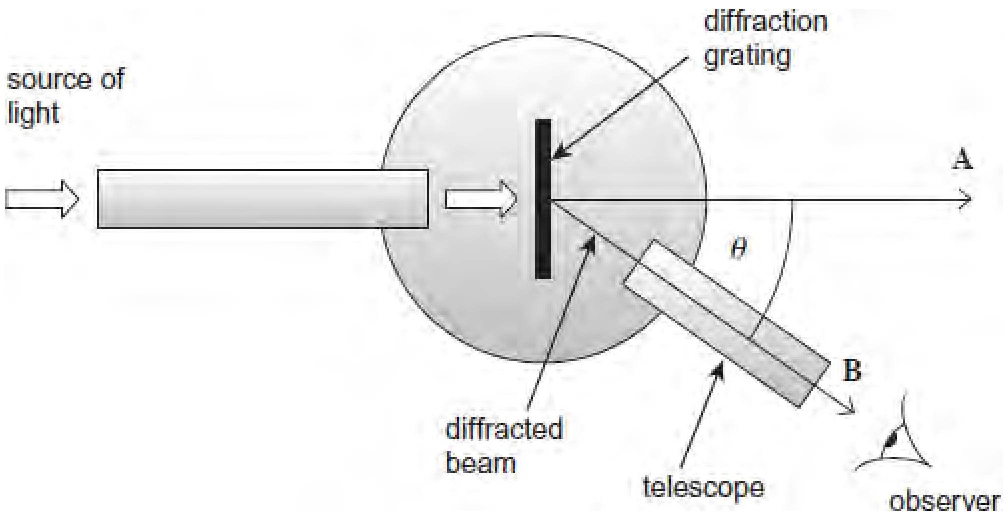

(1)

(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)

(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)

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

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

wavelength .... m

(3)

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

(2)
(Total 8 marks)

Q6.(a) A laser emits *monochromatic light*.

Explain the meaning of the term monochromatic light.

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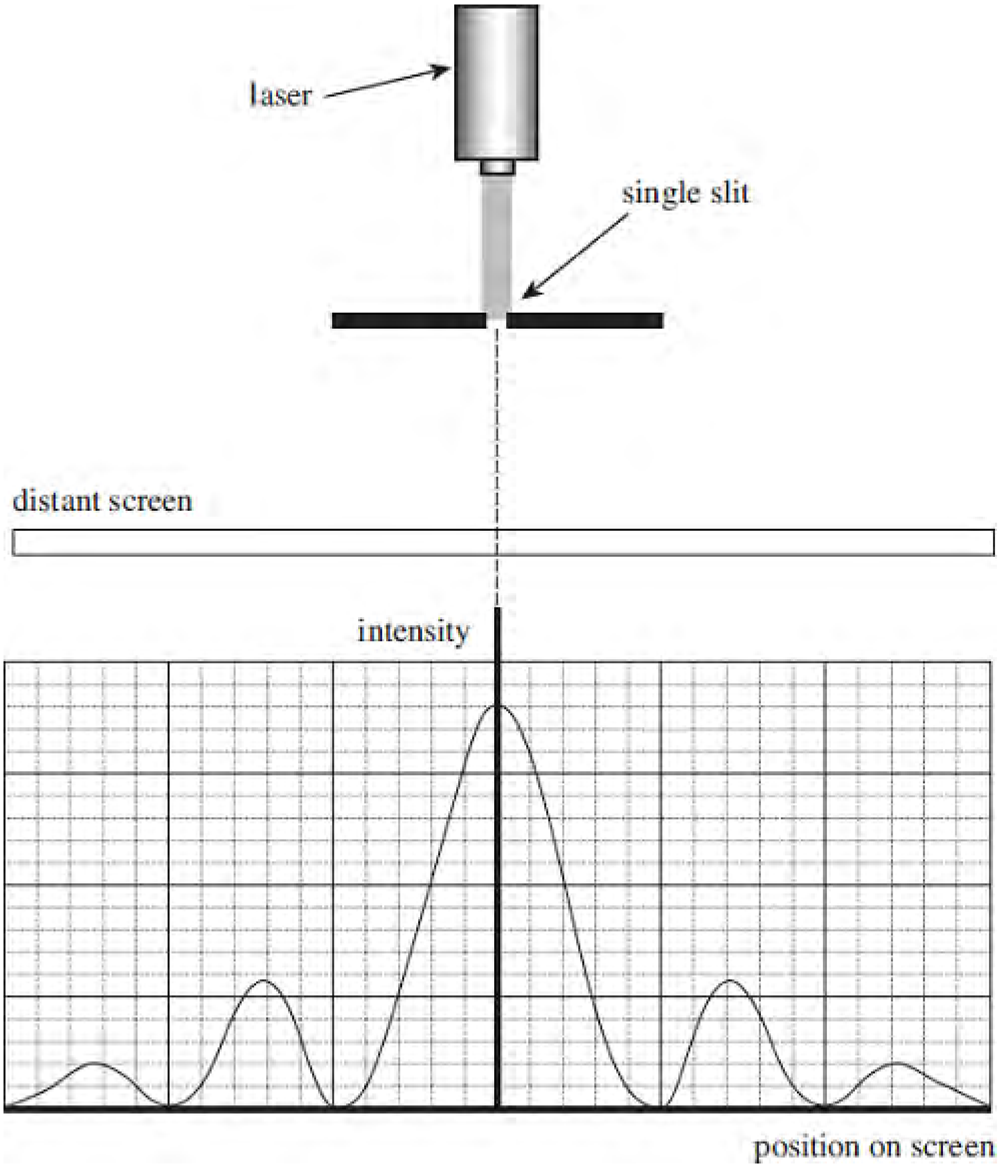
....

(1)

(b) The diagram below 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.



The laser is replaced by a laser emitting red light.

On the axes shown in the diagram above sketch the intensity graph for a laser emitting red light.

(2)

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

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(2)

(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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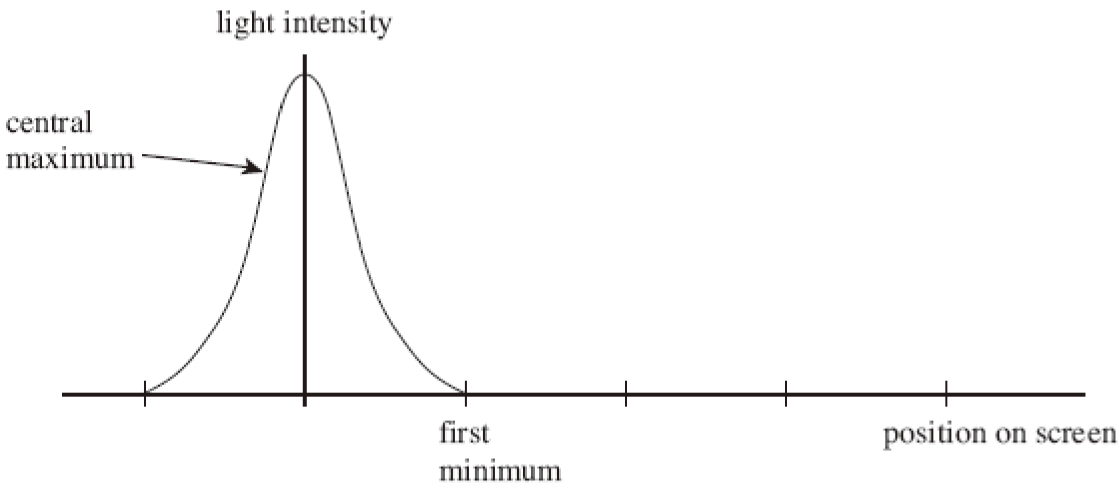
(3)
(Total 8 marks)

Q7. 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 the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(2)

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

monochromatic light ....

....

coherent light ....

....

(2)

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

....

....

(1)

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

....

....

(2)

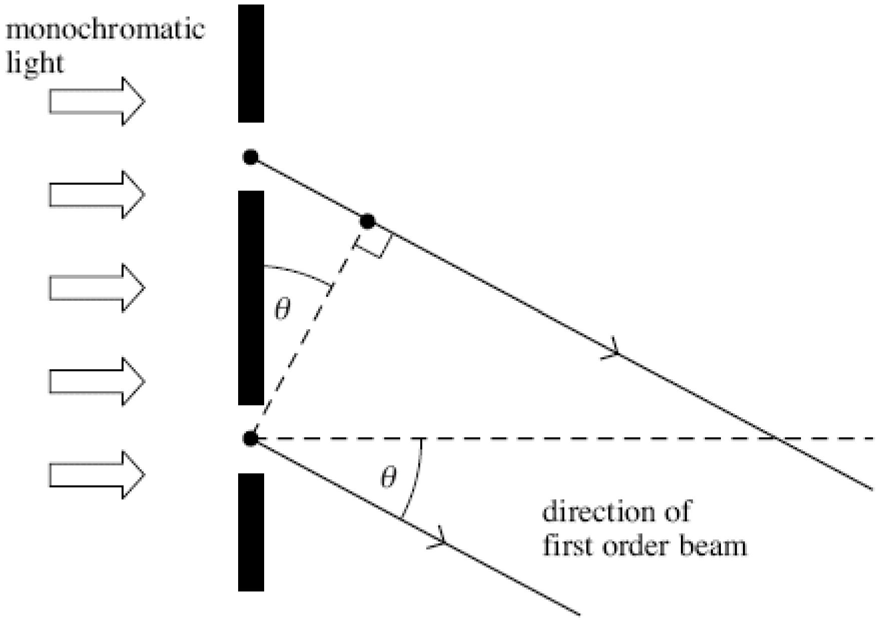
(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

(3)
(Total 10 marks)

Q8. For a plane transmission diffraction grating, the diffraction grating equation for the first order beam is:

$\lambda = d \sin \theta$

(a) The figure below shows two of the slits in the grating. Label the figure below with the distances *d* and *λ*.



(2)

(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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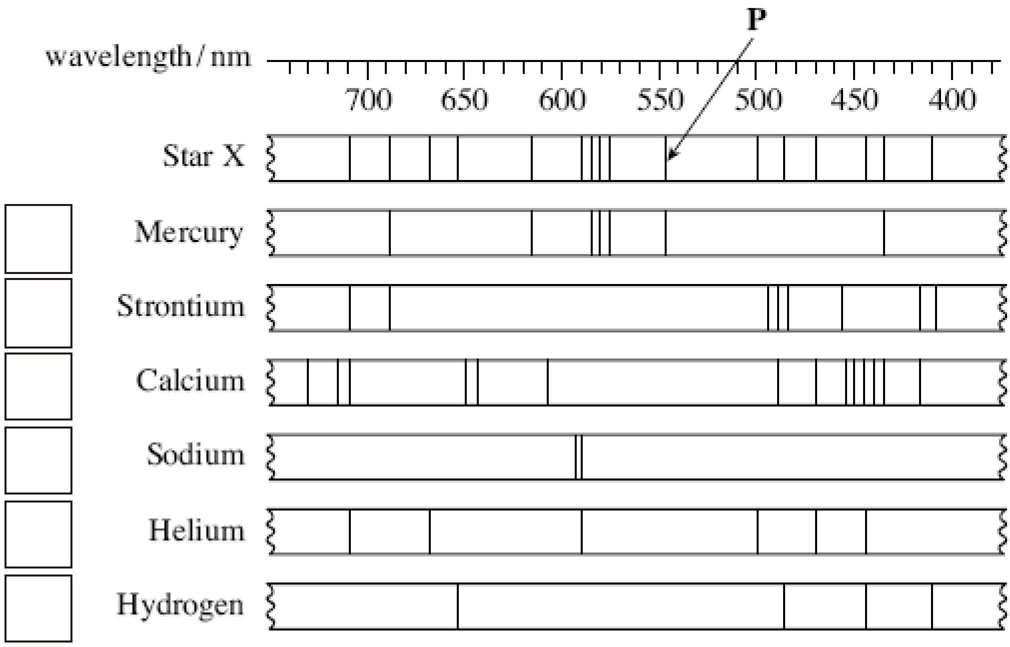
....

....

(2)

(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star **X** shown in the figure below. Shown 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)

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

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

answer = ... m

(1)

(ii) Calculate the first order angle of diffraction of line **P** in the figure above.

answer = ... degrees

(2)
(Total 9 marks)

Q9. A diffraction grating has 300 lines per mm. It is illuminated with monochromatic light of wavelength 540 nm.

Calculate the angle of the 2nd order maximum, giving your answer to the appropriate number of significant figures.

....

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....

....

angle .... degrees

(Total 4 marks)