Q1. 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?

....

....

(1)

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

(i) State what is meant by monochromatic.

....

....

(ii) State what is meant by coherent.

....

....

(2)

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

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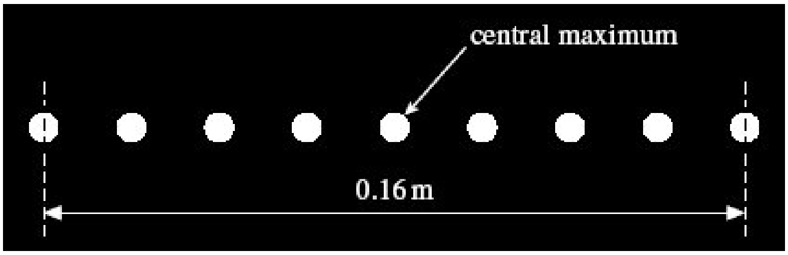
(1)

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



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

Use the diagram above to calculate the wavelength of the light that produced the pattern.

answer = ... m

(3)

(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)
(Total 9 marks)

Q2. A vertical screen is placed several metres beyond a vertical double slit arrangement illuminated by a laser. The diagram below shows a full-size tracing of the pattern of spots obtained on this screen. The black patches represent red light whilst the spaces between them are dark.

(a) Using the wave theory, explain how the pattern of bright and dark patches is formed. You may be awarded marks for the quality of written communication provided in your answer.

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(3)

(b) The slit separation was 0.90 mm and the distance between the slits and the screen was 4.2 m.

(i) Calculate the spacing of the bright fringes by taking measurements on the diagram of the tracing.

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(ii) Hence determine the wavelength of the laser light used.

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(4)
(Total 7 marks)

Q3. (a) State **two** requirements for two light sources to be coherent.

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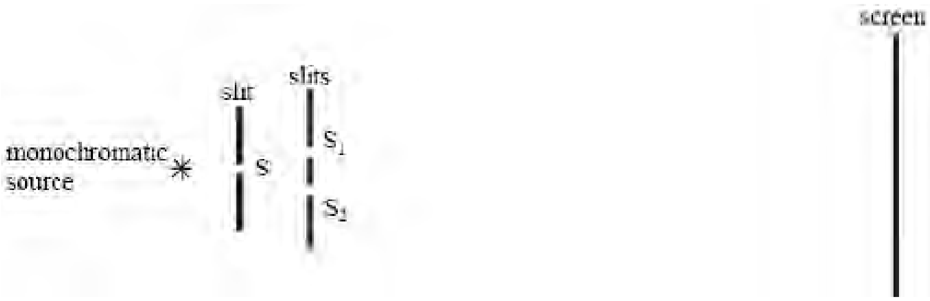
(2)

(b) **Figure 1**



Young's fringes are produced on the screen from the monochromatic source by the arrangement shown in **Figure 1**.
Explain how this arrangement produces interference fringes on the screen. In your answer, explain why slit S should be narrow and why slits S_1 and S_2 act as coherent sources.
The quality of your written answer will be assessed in this question.

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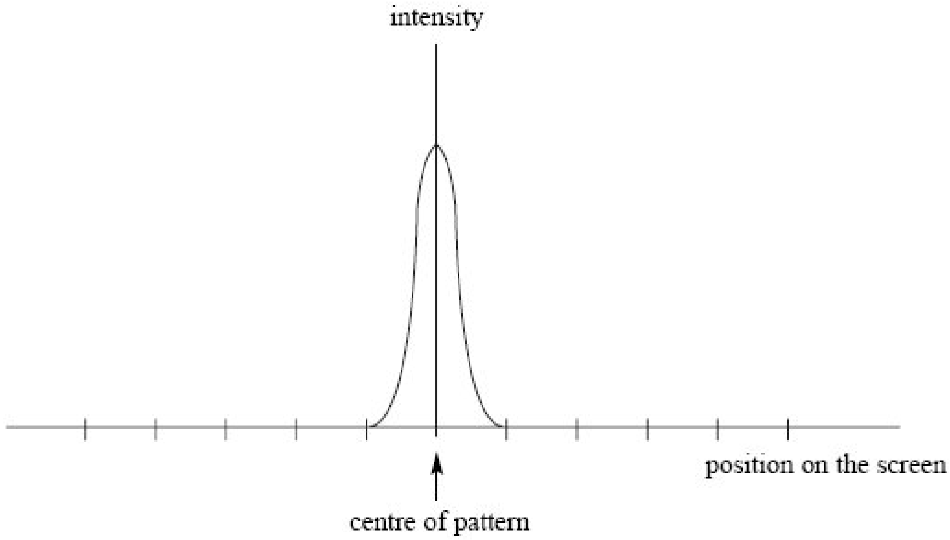
(6)

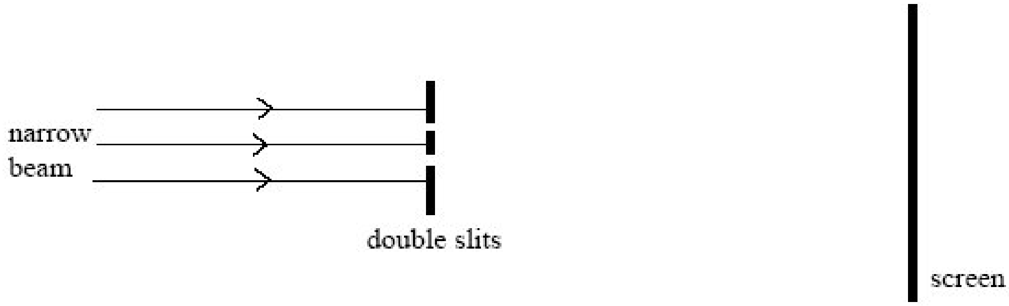
(c) The pattern on the screen may be represented as a graph of intensity against position on the screen. The central fringe is shown on the graph in **Figure 2**. Complete this graph to represent the rest of the pattern by drawing on **Figure 2**.

Figure 2



(2)
(Total 10 marks)

Q4. 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 the diagram above.



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

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(1)

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

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(4)

(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)

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

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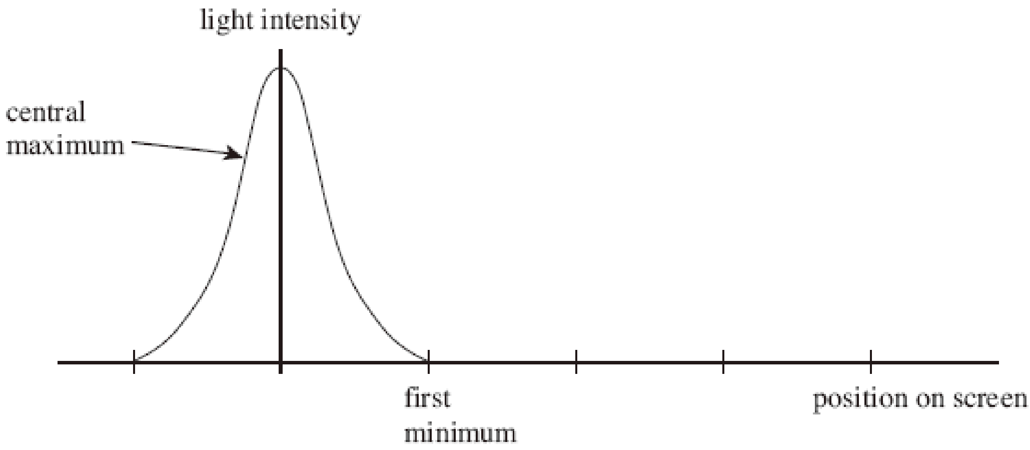
(3)

(Total 12 marks)

Q5. 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.

....

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(1)

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

....

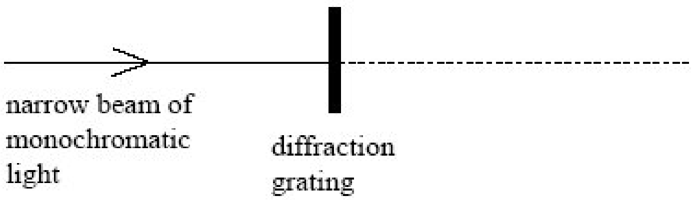
....

(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)

Q6. A narrow beam of monochromatic light of wavelength 590 nm is directed normally at a diffraction grating, as shown in the diagram below.



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

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

answer .... degrees

(4)

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

(3)

(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.

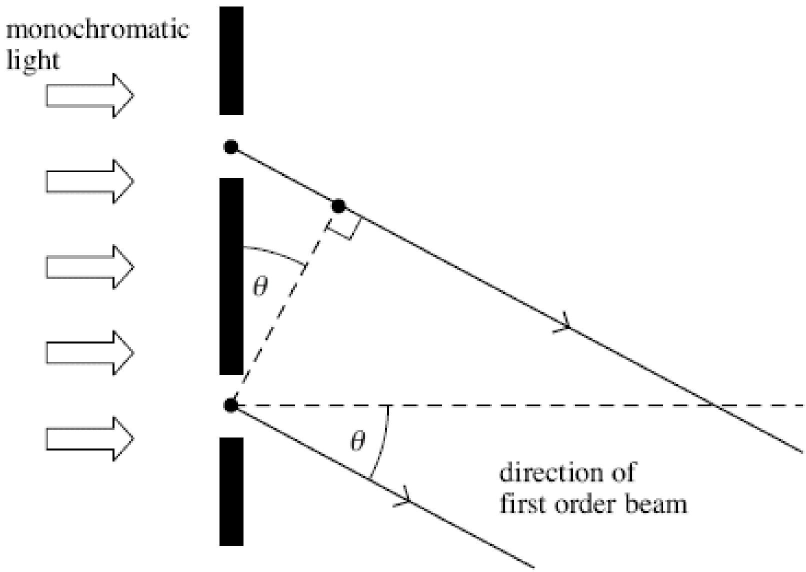
answer .... m

(2)
(Total 9 marks)

Q7. 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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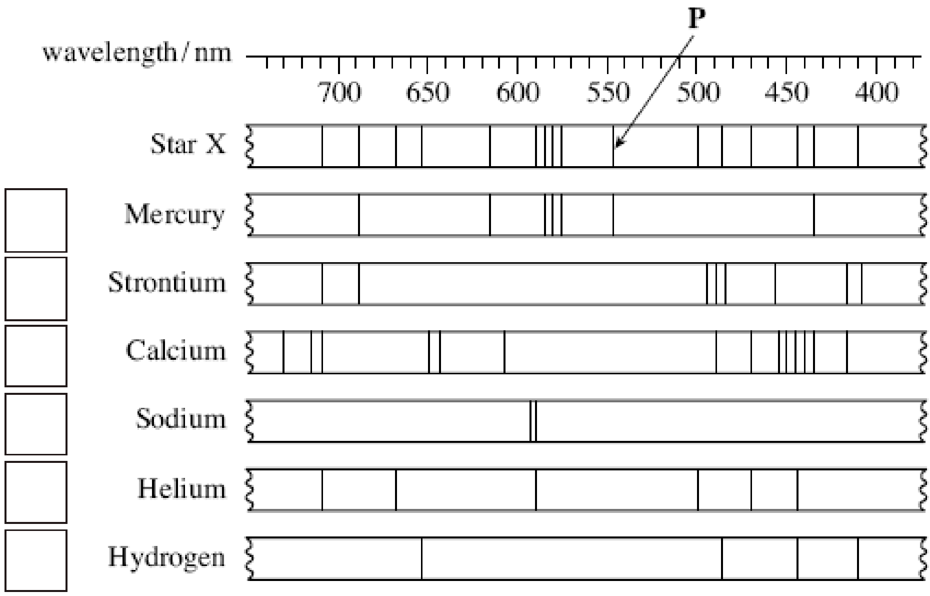
(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star **X** shown in the figure below. Shown are some line spectra for six elements that have been obtained in the laboratory.

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)

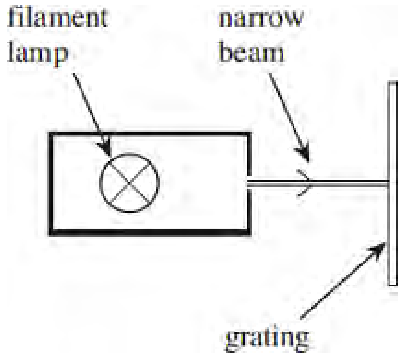
(ii) Calculate the first order angle of diffraction of line **P** in the figure above.

answer = ... degrees

(2)

(Total 9 marks)

Q8. (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 the figure below to show the light beams transmitted by the grating, showing the zero-order beam and the first-order beams.



(3)

(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)

(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.

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

(2)

(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)
(Total 13 marks)

M1. (a) showed that light was a **wave** (rather than a particle)/**wave** nature (of light) **(1)**

1

(b) (i) single wavelength (or frequency) **(1)**

1

(ii) (waves/source(s) have) constant phase difference **(1)**

1

(iii) any sensible precaution, eg do not look into laser/do not point the laser at others/do not let (regular) reflections enter the eye/safety signs/suitable safety goggles **(1)**

1

(c) (0.16/8) = 0.02(0) **(1)**

$= \dfrac{0.020 \times 0.30(\times 10^{-3})}{10.0}$ **(1)** ecf from calculation of fringe spacing

$= 6.0 \times 10^{-7}$ m **(1)** (= 600 nm) ecf from calculation of fringe spacing

3

(d) maxima closer together **(1)**

(quotes equation and states that) spacing is proportional to wavelength/ *D* and *s* are constant therefore as λ decreases so ω decreases **(1)**

or links smaller wavelength to smaller path difference **(1)**

2

[9]

M2. (a) slits act as coherent sources **(1)**
waves/light diffract at slits **(1)**
waves overlap/superpose/meet/cross **(1)**
bright patches : constructive/waves in phase/reinforce **(1)**
dark patches : destructive/waves out of phase/cancel **(1)**

max 3
QWC 2

(b) (i) spacing $w = \frac{76 \pm 1(mm)}{26}$ = 3.0 or 2.9 mm **(1)** (2.92 ± 0.04 mm)

15 or more fringes used **(1)**

(ii) (use of $\lambda = \frac{ws}{D}$ gives) $\lambda = \frac{2.92 \times 10^{-3} \times 0.90 \times 10^{-3}}{4.2}$ **(1)**

= 6.26×10^{-7}

(allow C.E. for sensible value of *w* from (i))

4

[7]

M3. (a) same wavelength or frequency **(1)**

same phase or constant phase difference **(1)**

2

(b) The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question.

Level	**Descriptor** an answer will be expected to meet most of the criteria in the level descriptor	**Mark range**
Good **3**	– answer includes a good attempt at the explanations required – answer makes good use of physics ideas including knowledge beyond that given in the question – explanation well structured with minimal repetition or irrelevant points and uses appropriate scientific language – accurate and logical expression of ideas with only minor/occasional errors of grammar, punctuation and spelling	**5-6**
Modest **2**	– answer includes some attempts at the explanations required – answer makes use of physics ideas referred to in the question but is limited to these – explanation has some structure but may not be complete – explanation has reasonable clarity but has a few errors of grammar and/or punctuation and spelling	**3-4**
Limited **1**	– answer includes some valid ideas but these are not organised in a logical or clear explanation – answer lacks structure – several errors in grammar, punctuation and spelling	**1-2**
0	– incorrect, inappropriate or no response	**0**

the explanations expected in a competent answer should include a coherent selection of the following physics ideas:

- narrow single slit gives wide diffraction
- to ensure that both S_1 and S_2 are illuminated
- slit S acts as a point source
- narrow single slit ensures it provides coherent sources of light at S_1 and S_2
- S_1 and S_2 are illuminated by same source giving same wavelength
- paths to S_1 and S_2 are of constant length giving constant phase difference or SS_1 and SS_2 so waves are in phase
- light is diffracted as it passes through S_1 and S_2 and the diffracted waves overlap and interfere
- where the path lengths from S_1 and S_2 to the screen differ by whole numbers, n of wavelengths, constructive interference occurs producing a bright fringe on the screen
- where the path lengths differ by (n + ½) wavelengths, destructive interference occurs producing a dark fringe on the screen

(c) graph to show: maxima of similar intensity to central maximum **(1)**
(**or** some decrease in intensity outwards from centre)

all fringes same width as central fringe **(1)**

2

[10]

M4. (a) (i) **diffraction (1)**

(ii) **any 4 points from**

interference (fringes formed) **(1)**

where light from the two slits overlaps (or superposes) **(1)**

bright (or red) fringes are formed where light (from the two slits) reinforces (or interfere constructively/crest meets crest) **(1)**

dark fringes are formed where light (from the two slits) cancels (or interferes destructively/trough meets crest) **(1)**

the light (from the two slits) is coherent **(1)**

either
reinforcement occurs where light waves are in phase
(or path difference = whole number of wavelengths) **(1)**

or
cancellation occurs where light waves are out of phase of 180°
(in anti-phase)
(or path difference = whole number + 0.5 wavelengths) **(1)**
(not 'out of phase')

(iii) $\left(w = \dfrac{\lambda D}{s}\right)$ gives $\lambda = \dfrac{ws}{D}$ **(1)**

w (= 3.6/**4**) = 0.9(0) mm **(1)** (failure to /4 is max 2)

$\lambda \left(= \dfrac{ws}{D}\right) = \dfrac{0.90 \times (10^{-3}) \times 0.56 \times (10^{-3})}{0.80}$ **(1)** = 6.3×10^{-7} m **(1)**

9

(b) central (bright) fringe would be white **(1)**

side fringes are (continuous) spectra **(1)**

(dark) fringes would be closer together (because λ_{red} > average λ_{white}) **(1)**

the bright fringes would be blue on the side nearest the centre
(or red on the side away from the centre) **(1)**

bright fringes merge away from centre **(1)**

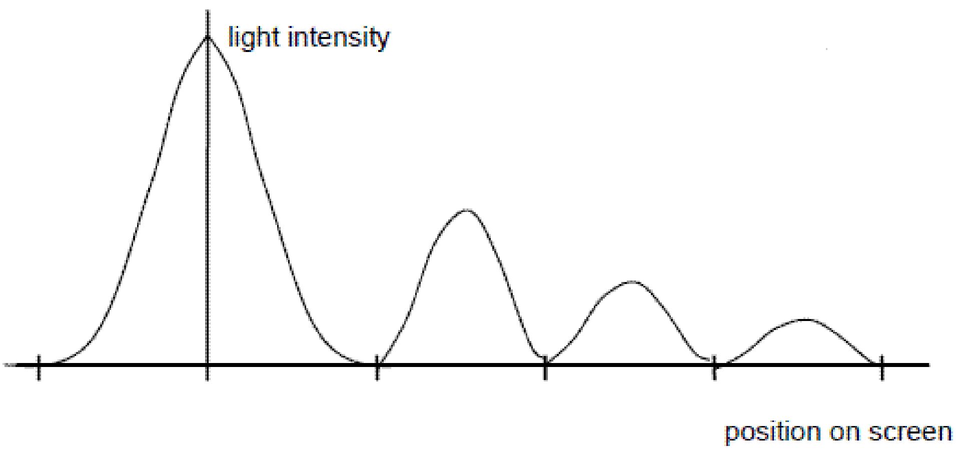
bright fringes wider (or dark fringes narrower) **(1)**

max 3

[12]

M5. (a) 3 subsidiary maxima in correct positions **(1)**

intensity decreasing **(1)**



2

(b) a single wavelength **(1)**

constant phase relationship/difference **(1)**

2

(c) maxima further apart/central maximum wider/subsidiary maximum wider/maxima are wider **(1)**

1

(d) wider/increased separation **(1)**

lower intensity **(1)**

2

(e) distinct fringes shown with subsidiary maxima **(1)**

indication that colours are present within each subsidiary maxima **(1)**

blue/violet on the inner edge **or** red outer for at least one subsidiary maximum **(1)**

(middle of) central maximum white **(1)**

3

[10]

M6. (a) (i) $= 590 \times 10^{-9}$m **(1)**

(using $d \sin \theta = n\lambda$ gives)

$\sin \theta = \frac{n\lambda}{d}$ or $= \frac{2 \times 590 \times (10^{-9})}{1.67 \times 10^{-6}}$ **(1)** = **0.707** or

7.07×10^{8} if nm used **(1)**

$\theta = 45.0°$ **(1)** (accept 45°)

(ii) ($\sin \theta \leq 1$) gives $\frac{n\lambda}{d} \leq 1$ or $n \leq \frac{d}{\lambda}$ or $= \frac{1.67 \times 10^{-6}}{590 \times 10^{-9}}$ **(1)** = 2.83 **(1)**

so 3rd order or higher order is not possible **(1)**

alternative solution:
(substituting) ***n* = 3** (into $d \sin \theta = n\lambda$ gives) **(1)**

$\sin \theta$ (= $\frac{n\lambda}{d} = \frac{3 \times 590 \times 10^{-9}}{1.67 \times 10^{-6}}$) = 1.06 **(1)**

gives 'error'/which is not possible **(1)**

7

(b) (using $d \sin \theta = n\lambda$ gives)

$2\lambda = 1.67 \times 10^{-6} \times \sin 42.1$ **(1)**

$\lambda(= 0.5 \times 1.67 \times 10^{-6} \times \sin 42.1) = 5.6(0) \times 10^{-7}$ m (or 560 nm) **(1)**

2

[9]

M7. (a) λ correct **(1)**

d correct **(1)** arrow or line needed, both ends extending beyond central black line

2

(b) angle θ gets smaller **(1)**

because path difference gets smaller/***d* constant**, (λ smaller) so $\sin \theta$ smaller **(1)**

max 1 for correct explanation for λ increasing

2

(c) boxes 1,5,6 **(1)(1)**

two correct 1 mark

4 ticks max 1

5 or 6 ticks gets 0

2

(d) (i) 3.3×10^{-6} m **(1)** ($1/300 = 3.33 \times 10^{-3}$ **mm**, 3300 **nm**) DNA 1 sf here DNA 1/300 000 as answer

accept 3 1/3 × 10^{-6}, 3.33 × 10^{-6} recurring, etc

1

(ii) ($\sin \theta =$) $\dfrac{540 \text{ to } 560 \times (10^{-9})}{((d)(i))}$ **(1)**

correct wavelength used and seen (**545 to 548 × 10^{-9}**)

and 9.4 to 9.6 (°) **(1)** ecf (d) (i), for correct wavelength only (545 to 548 × 10^{-9})

2

[9]

M8. (a) **max three from**

central maximum shown ✓

two equally spaced first order maxima ✓

central and one first order labelled correctly ✓

central white maximum ✓

indication of spectra/colours in at least one first order beam ✓

at least one first order beam labelled with violet (indigo or blue) closest to the centre **or** red furthest ✓

3

(b) **dark/black** lines **or** absorption spectrum **or** Fraunhofer lines ✓

(reveal the) composition (of the star's atmosphere) ✓

accept dark 'bands'

accept atoms or elements in the star

or the peak of intensity ✓

(is related to) the temperature ✓

or Doppler (blue or red) shift ✓

(speed of) rotation **or** speed of star (relative to Earth) ✓

2

(c) (i) grating and screen shown with both labelled ✓

laser or laser beam labelled ✓

2

(ii) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

- correct use of $(n)\lambda = d \sin \theta$
- **and** measure appropriate angle (eg 'to first order beam' is the minimum required)
- **and** method to measure angle (eg $\tan \theta = x/D$, spectrometer, accept protractor)
- **and** at least **one** way of improving accuracy/reliability
- for **full** marks: also explain how d is calculated, eg d = 1/ lines per mm ($\times 10^3$)

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

- use of $(n)\lambda = d \sin \theta$
- **and** measure appropriate angle (eg 'to first order beam' is the minimum required)
- **and** method of measurement of θ (eg $\tan \theta = x/D$, spectrometer, accept protractor) or at least one way of improving accuracy/reliability

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

- use of $(n)\lambda = d \sin \theta$
- **or** measure appropriate angle (eg 'to first order beam' is the minimum required)
- **or** at least **one** way of improving accuracy/reliability

Incorrect, inappropriate of no response: 0 marks

No answer or answer refers to unrelated, incorrect or inappropriate physics.

The explanation expected in a competent answer should include

Accuracy/reliability points

- measure between more than one order (eg 2 θ)
- measure θ for different orders (for average λ **not average angle**)
- check or repeat/repeat for different distances (D)
- use of spectrometer
- use large distance to screen (D)
- protractor with 0.5 degree (or less) intervals
- graphical method: **plot sin θ against n** (gradient = λ/d)

6

[13]