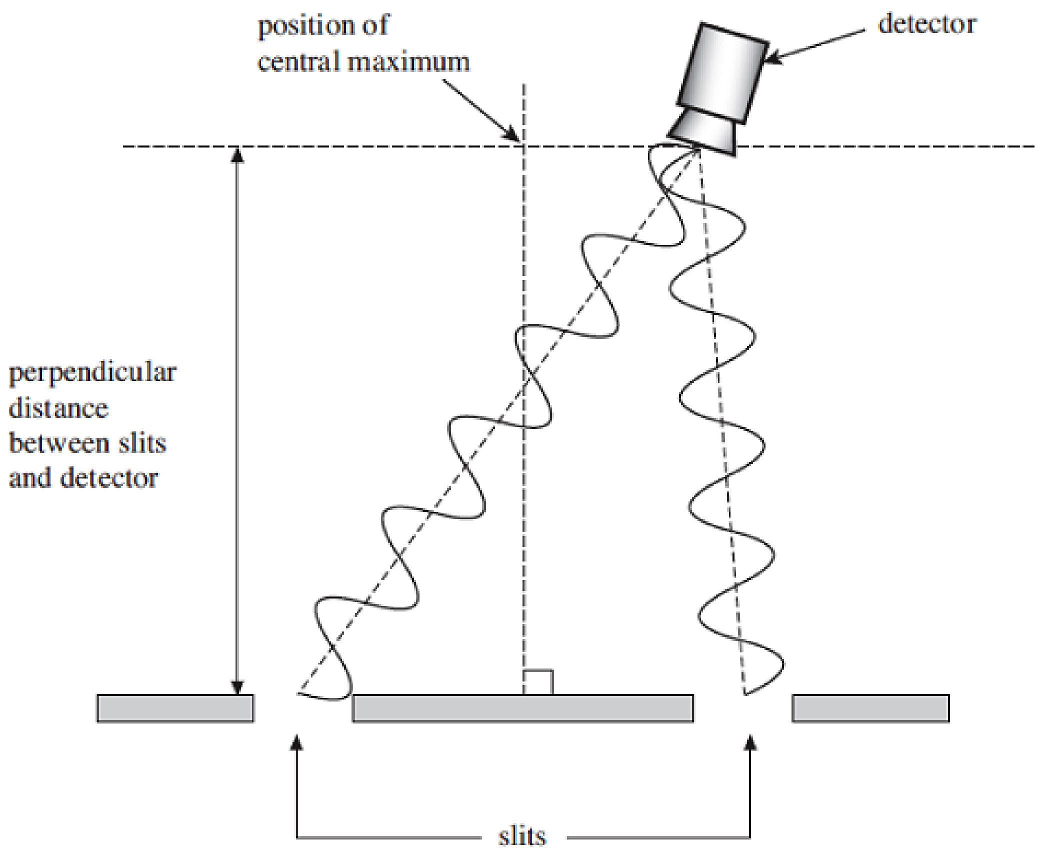
Q1. The diagram below shows the paths of microwaves from two narrow slits, acting as coherent sources, through a vacuum to a detector.



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

....

....

....

....

(2)

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

Calculate the wavelength of the waves.

wavelength = ... m

(2)

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

path difference = ... m

(1)

(c) State and explain whether a maximum or minimum is detected at the position shown in the diagram above.

....

....

....

....

(3)

(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)

(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.

....

....

....

....

(3)
(Total 14 marks)

Q2. 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.

....

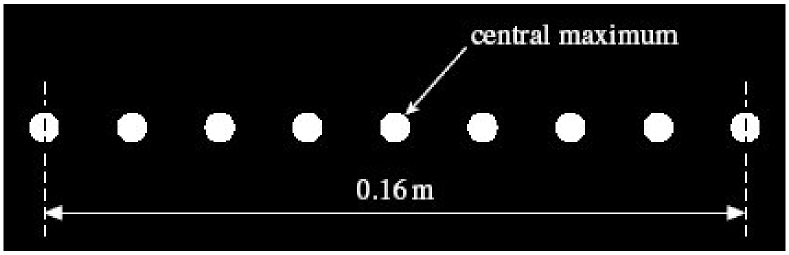
.... **(2)**

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

....

.... **(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.

....

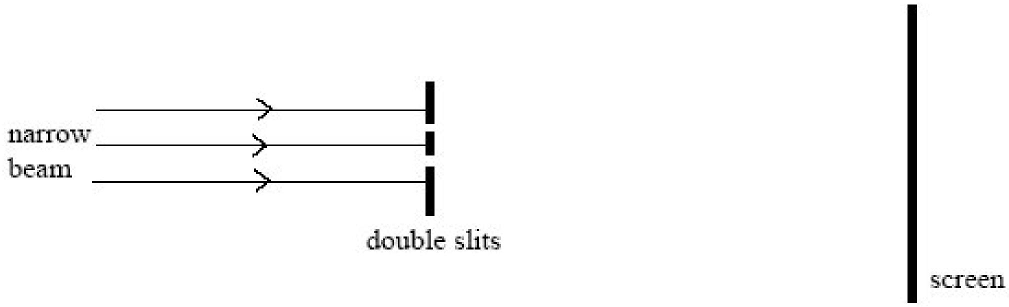
....

....

....

(2)
(Total 9 marks)

Q3. 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?

....

(1)

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

....

....

....

....

....

....

....

....

(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.

....

....

....

....

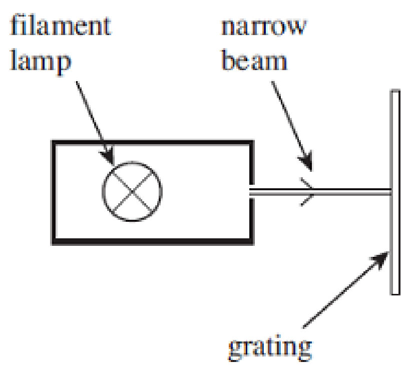
....

....

....

(3)
(Total 12 marks)

Q4. (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.

....

....

....

....

(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.

....

....

....

....

....

....

....

....

....

....

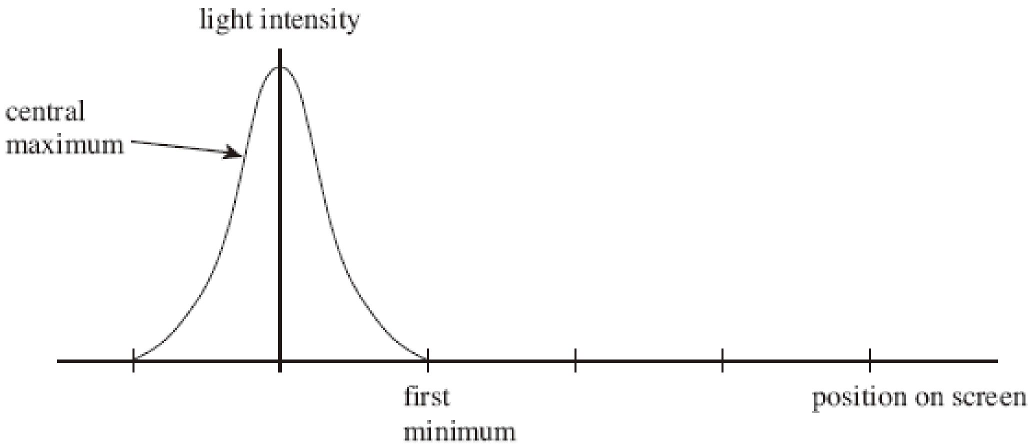
....

....

....

(6)
(Total 13 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.

....

....

(1)

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

....

....

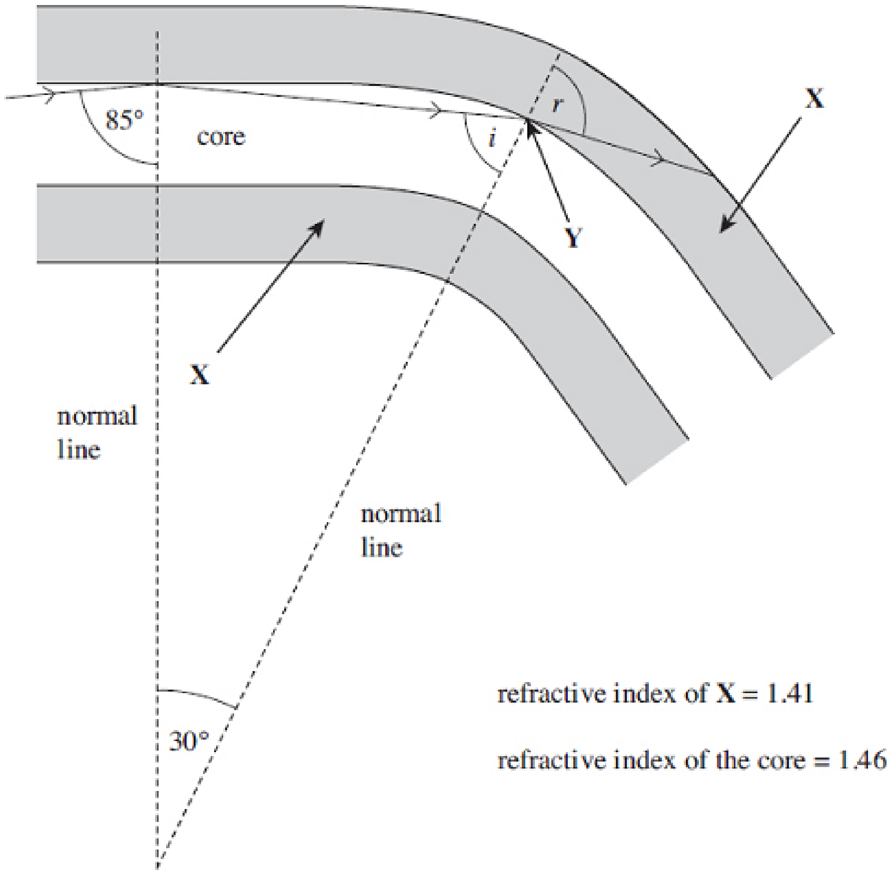
(2)

(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. **Figure 1** shows a cross-section through an optical fibre used for communications.

Figure 1



(a) (i) Name the part of the fibre labelled **X**.

....

(1)

(ii) Calculate the critical angle for the boundary between the core and **X**.

answer = ...degrees

(2)

(b) (i) The ray leaves the core at **Y**. At this point the fibre has been bent through an angle of 30° as shown in **Figure 1**.

Calculate the value of the angle *i*.

answer = ...degrees

(1)

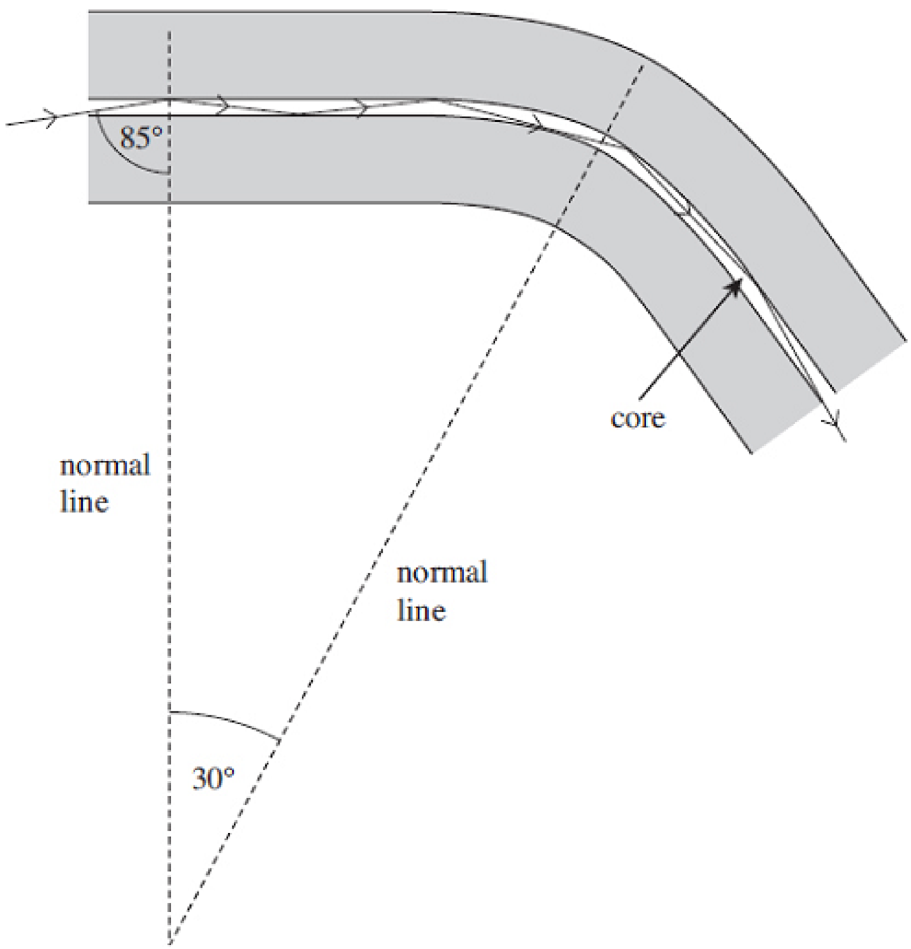
(ii) Calculate the angle *r*.

answer = ...degrees

(2)

(c) The core of another fibre is made with a smaller diameter than the first, as shown in **Figure 2**. The curvature is the same and the path of a ray of light is shown.

Figure 2



(c) State and explain **one** advantage associated with a smaller diameter core.

....

....

....

....

....

(2)
(Total 8 marks)

M1. (a) same wavelength / frequency ✓

constant phase relationship ✓ allow 'constant phase difference' but not 'in phase'

2

(b) (i) ($\lambda = \frac{c}{f}$)

Use of speed of sound gets zero

$3.00 \times 10^8 = 9.4\ (10^9)\ \lambda$ OR $\frac{3.00\times10^8}{9.4\times(10^9)}$ ✓

$= 3.2 \times 10^{-2}$ (3.19×10^{-2} m) ✓

Allow 0.03

2

(ii) 3.2×10^{-2} ✓ (m) ecf from bi

Don't allow '1 wavelength', 1λ, etc
Do not accept: zero, 2π, 360 °

1

(c) maximum (at position shown) ✓

allow constructive superposition.
'Addition' is not enough

constructive interference / reinforcement ✓

ecf for 'minimum' or for reference to wrong maximum

(the waves meet) 'in step' / peak meets peak / trough meets trough / path difference is (n) λ / in phase ✓

3

(d) $s = \frac{\lambda D}{w}$

Don't allow use of the diagram shown as a scale diagram

$= \frac{0.0319\times0.42}{0.11}$ ✓ ecf bi

Do not penalise s and w symbols wrong way round in working if answer is correct.

= 0.12 (0.1218 m) ✓

Correct answer gains first two marks.

= **any** __**2sf**__ number ✓

Independent sf mark for ***any*** *2 sf number*

3

(e) a maximum ✓

Candidates stating ' minimum ' can get second mark only

(f × 2 results in) $\lambda/2$ ✓

path difference is an even number of multiples of the new wavelength ($2n\lambda_{new}$) ✓

allow 'path difference is $n\lambda$' / any even number of multiples of the new λ quoted e.g. 'path difference is now 2 λ'

3

[14]

M2. (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)**

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

= 6.0×10^{-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]

M3. (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) $\left(w = \frac{\lambda D}{s}\right)$ gives $\lambda = \frac{ws}{D}$ **(1)**

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

$\lambda \left(= \frac{ws}{D}\right) = \frac{0.90 \times (10^{-3}) \times 0.56 \times (10^{-3})}{0.80}$ **(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]

M4. (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

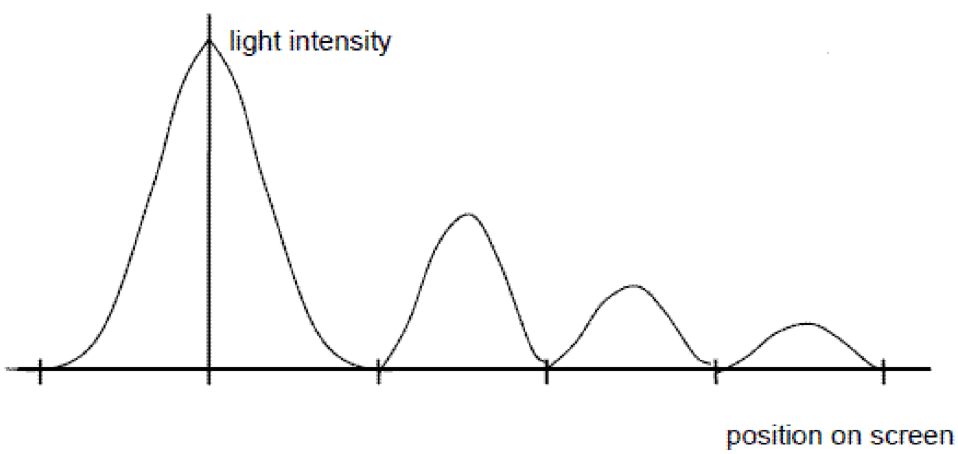
- measure between more than one order (eg 2 θ)
- measure θ for different orders (for average λ **not average angle**)
- check or repeat/repeat for different distances (D)
- use of spectrometer
- use large distance to screen (D)
- protractor with 0.5 degree (or less) intervals
- graphical method: **plot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

6

[13]

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) <u>cladding</u> ✓

1

(ii) $\sin \theta_c = 1.41/1.46$ ✓

$\theta_c = 75.0$ (°) (74.96) ✓

2

(b) (i) 65 (degrees) ✓

1

(ii) 1.46 sin 65 = 1.41 sin r **or** sin r = 0.93845 ✓ ecf bi

r = 70 ✓ (degrees) (69.79) ecf bi

2

(c) Two from:

- less light is lost
- better quality signal / less distortion
- increased probability of TIR
- Less change of angle between each reflection
- reflects more times (in a given length of fibre) keeping (incident) angle large(r than critical angle)
- (angle of incidence is) less likely to fall below the <u>critical angle</u>
- less <u>refraction</u> out of the core
- improved data transfer / <u>information / data / signal</u> carried quicker
- less multipath dispersion (smearing / overlap of pulses)

✓ ✓

2

[8]