Question	Answer	Marks	Guidance
1 (a) (i)	1.52 sin *c* = 1.35 sin 90 gives sin *c* = 0.888. Hence *c* = 62.6 °	1 1 1	Tests the ability to calculate the critical angle for a boundary between two transparent substances, given the refractive index of each and then to apply that to sketch the path of a light ray in an optical fibre.
1 (a) (ii)	light ray confined to core angle of incidence > 62.6 ° more than one total internal reflection shown	1 1 1	
1 (b) (i)	Total internal reflection takes place at the core-cladding boundary so the light rays stay in the core. If two fibres are in contact, light cannot pass from one fibre to the other because it is confined to the core of each fibre. Without cladding, the cores would be in contact and light could pass from one fibre to another where they are in contact. Light signals in each fibre would therefore not be secure.	1 1 1 1	Knowledge of total internal reflection and critical angle needs to be applied to explain why cladding of optical fibres is necessary. A general statement about the need to make prevent light crossing over where fibres are in contact for security purposes should be backed up by relevant physics points about why cladding fulfils this function.
1 (b) (ii)	Benefits; security camera intended to deter unauthorised access; data is more secure in transmission using optical fibre than other methods; image storage enables past images to be viewed if necessary Drawbacks; security camera could be disconnected, stored images could be deleted or misused.	3	3 marks maximum Provides an opportunity to discuss the wider benefits of fibre optics used to transmit images from a security camera. The key physics point to make is that the use of an optical fibre enables video images to be transmitted securely and stored if necessary.
2 (a)	Ray drawn to show: • total internal reflection at right hand interior face of glass block • ray emerging from base of block into the air • refracted away from normal	3	Use a ruler and draw in the normals at the points where the ray meets a boundary. You are told that the critical angle of the glass is 45 °; therefore the ray incident at 50 ° must experience total internal reflection down to the base of the block. At this point it will emerge into the air (because the angle of incidence is only 40 °), bending away from the normal as it does so.
2 (b)	use of $\sin \theta_C = \frac{n_2}{n_1}$ gives $n_1 = \frac{1.00}{\sin 45\#°} = 1.41$	1 1	For the critical condition to occur, the light must be travelling from a more dense medium (refractive index n_1) to a less dense medium (refractive index n_2). In this case, from glass to air. You are asked to show that the value is 1.41, making it even more important to write down the steps in your working.

Question	Answer	Marks	Guidance
2 (c)	use of $n_1 \sin \theta_1 = n_2 \sin \theta_2$ gives $1.00 \sin \theta = 1.41 \sin 40°$ ∴ angle of incidence $\theta = 65.0°$	1 1 1	The angle of refraction (within the glass at the top surface) is 40° because the angle between the refracted ray and the top surface is 50 ° (alternate angles).
3 (a) (i)	Completed diagram to show: • ray refracting towards the normal on entry • total internal reflection at the surface, several times along the fibre • refraction away from the normal on emerging from the right hand end of the fibre	3	Use a ruler to draw the path of the ray, and mark in the normals at each reflection and at the point of emergence. At each reflection, you should try to show that the path of the ray satisfies (angle of incidence = angle of reflection) as accurately as you can.
3 (a) (ii)	the speed of light decreases when it enters the glass fibre and increases again when it emerges into the air	1	The speed of light depends only on the nature of the material through which it is travelling. The speed always has the same value in the same medium, but decreases in an optically denser medium.
3 (b) (i)	use of $\sin \theta_C = \frac{n_1}{n_2} = \frac{1.00}{1.57}$ gives $\theta_C = 39.6°$	1 1	In **(i)** you are dealing with an optical fibre that has air surrounding it. The subscripts refer to a ray travelling from medium 1 (glass, $n_1 = 1.57$) towards medium 2 (air, $n_2 = 1.00$).
3 (b) (ii)	use of $\sin \theta_C = \frac{n_2}{n_1} = \frac{1.47}{1.57}$ $= 0.936$ gives $\theta_C = 69.4°$	1 1 1	In **(ii)** the optical fibre is surrounded by cladding that has a higher refractive index than air, but less than the glass. The effect of this is to increase the critical angle substantially.
3 (b) (iii)	Advantage of cladding: • the cladding protects the surface of the core • it also prevents cross-over between adjacent fibres	any 1	Surface imperfections, such as scratches on the fibre, can prevent the fibre from reflecting light along its length. Cladding protects the surface of the fibre from such damage. If perfect contact is made between glass fibres in a bundle of fibres that have no cladding, light can pass from one to the next. This cannot happen if the fibres have cladding.

Question	Answer	Marks	Guidance
4 (a)	Coherent sources of light produce: • waves of the same wavelength (or frequency) • waves that have a constant phase difference (which may be zero)	2	To be coherent, the waves do not need to have the same amplitude, nor do they **need** to be in phase (any constant phase relation is sufficient). It can be argued that waves having a constant phase difference must also have the same frequency, but you will probably make your understanding clearer by stating both of the points in the answer opposite.
4 (b) (i) 4 (b) (ii)	Relevant points include: • the narrow slit produces wide diffraction of the light waves • to ensure that both S_1 and S_2 are illuminated • slit S acts as a point source • S_1 and S_2 are illuminated from the same source, giving monochromatic light of the same wavelength • the paths from S to S_1 and from S to S_2 are of constant length, giving a constant phase difference between the waves	4	It is important for slits S_1 and S_2 to be placed within the central intensity maximum of the single slit diffraction pattern produced by light passing through S. If S were to be too wide, S_1 and S_2 could coincide with the first minimum of this pattern. No light would then pass through them. Note that (in terms of the extremely small wavelength of light) it is most unlikely that SS_1 and SS_2 could ever be exactly the same length. It is the constant path difference between these lengths that ensures there is a constant phase difference.
4 (c)	Graph completed to show: • maxima of similar intensity to the central maximum • all fringes having the same width as the central fringe (i.e. 2 divisions on the horizontal scale)	2	Don't confuse this with the single slit diffraction pattern, where the central fringe is twice the width of the others and there is a great falling-off of intensity outwards from the centre. You are probably more accustomed to seeing a photograph of the Young's slits pattern than having to deal with a graph of it.
5 (a)	distance between adjacent lines $d = \frac{1}{n} = \frac{1}{940 \times 10^3} = 1.06 \times 10^{-6}$ m	1	There are 940 lines per mm, which is 940 × 103 lines per metre.
5 (b)	for the second order spectral line, $2\lambda = d \sin\theta$ $\lambda = \frac{1}{2} \times 1.06 \times 10^{-6} \times \sin 55°$ $= 4.3 \times 10^{-7}$ m	1 1 1	The diffraction grating can be used to find an unknown wavelength in this way provided *d* is known. Use of the second order image offers the advantage that u is larger (and can therefore be measured more accurately). However, the second order image is fainter and often less well defined than the first order image.