1. (a) (i) **NORMAL** B1 [1]

(ii) recall of $n = \sin i / \sin r$ C1
valid substitution: e.g. 1.31 = sin 60/sinr C1
r = **41°** (allow 41.3 and 41.4) A1 [3]

(iii) ray refracted **TOWARDS** NORMAL (NO ARROW NEEDED) B1
angle of refraction r or '41' labelled between ray and normal B1 [2]

(iv) light CHANGES SPEED (or slows down) B1 [1]

(b) RI or $n = \lambda_1/\lambda_2$ C1
new wavelength = $6.5 \times 10^{-7}/1.3$ = **5.0×10^{-7}** m (expect 4.96) A1 [2]

4.44×10^{-7} comes from 41/60 x 6.5×10^{-7} and scores ZERO
8.45×10^{-7} comes from 6.5×10^{-7} x 1.3 scores 1 mark

(c) NO CHANGE OF DIRECTION (judged by eye) B1 [1]
wavefronts CLOSER TOGETHER (uniformity generously judged by eye) -B1 [1]

QUESTION TOTAL = 11

2. (a) ray leaving S that is internally reflected at the core/cladding interface B1
LARGE angle of incidence – i.e no more than **3** points of contact/reflections shown B1 [2]
(sine wave may score second mark only)

(b) 1. R.I of core > R.I of cladding (OR density of core>density of cladding) B1
(allow " light must travel from dense to less dense medium" WTTE)

2. <u>angle</u> of incidence greater than the critical angle (WTTE) B1 [2]

(c) *explanation of change of shape:*
different rays follow different paths OR reference to "multipath dispersion" B1
some rays arrive before others (WTTE referring to time) B1
(allow 1 mark for idea of energy or intensity loss
(allow 1 mark for idea that light of different wavelengths travel at different speeds)

explanation of how problem is overcome:
<u>any</u> valid method: e.g use a very narrow fibre OR a MONOMODE fibre B1
so that effectively there is only one path (WTTE) B1 [4]

(d) (Light is moving from core to cladding hence correct formula for n is)
n = sinC C1
n = sin 80 = **0.985** (allow 0.98) A1

Allow simple <u>substitution</u> into n = 1/sinC: e.g. n = 1/sin80 C1
n = **1.02** (allow 1.0 or 1 if sin80 is seen) A1 [2]

QUESTION TOTAL = 10

3. (a) any **two** valid points: e.g
in longitudinal waves the vibrations are parallel to wave direction (WTTE) }
in transverse waves the vibrations are perpendicular to wave direction (WTTE) }
transverse waves <u>can</u> be polarised (OR longitudinal waves are not be polarised) }
(all) longitudinal waves need a medium } B1+B1 [2]

(b) (i) vibrations "V" correctly labelled OR (NOT) B1 [1]
(ii) compression "C" correctly shown anywhere on the spring B1 [1]
(iii) wavelength "λ" correctly shown: e.g. between neighbouring compressions B1 [1]
(generously judged: i.e. somewhere between 28 and 34 mm)

(c) wavelength REDUCES B1
because v=fλ AND v remains constant (WTTE) B1 [2]

QUESTION TOTAL = 7

4. (a) DIFFRACTION B1 [1]

(b) a constant phase difference/relation (WTTE) B1 [1]
(allow "zero phase difference" and "in phase")

(c) constructive interference produces bright lines <u>AND</u> destructive for dark lines B1

in phase for bright AND antiphase (allow 'out of phase') for dark B1
(ALLOW diagrams showing crests/troughs meeting crests/troughs for this mark)
path difference = whole number of wavelengths {allow nλ} for bright B1
(ALLOW path difference = λ but NOT path difference = ZERO)
path difference = odd number of half wavelengths {allow (n+1/2)λ} for dark B1 [4]
(ALLOW path difference = ½λ)

(d) recall of $\lambda = ax/D$ (in any valid form) C1
valid substitution: e.g. $x = (6.5\times10^{-7}\times1.5)/0.25\times10^{-3}$ C1
$x = \mathbf{3.9 \times 10^{-3}}$ m A1 [3]
(3.9×10^{-6} scores 2 marks)

QUESTION TOTAL = 9

5. (a) (i) node: point of ZERO amplitude/displacement/movement/disruption etc. B1 [1]
(ii) antinode: a point of MAXIMUM **<u>AMPLITUDE</u>** B1 [1]

(b) (i) node **N** labelled at the bottom AND antinode **A** labelled at the top M1
evidence of 'fundamental' i.e only <u>one</u> **A** at top and <u>one</u> **N** at bottom A1 [2]
{allow ecf from (a) i.e. if A and N are defined oppositely}

(ii) (length of air column = ¼λ) ⇒ λ = 4 x 0.32 = **1.28** m B1 [1]
{NO ecf from incorrect wave in (i)}

(iii) recall of v=f λ OR frequency of tuning fork = frequency of standing wave C1
valid substitution: e.g f = 330/1.28 C1
f = **258** Hz A1 [3]
{allow ecf from(ii) e.g if λ= 0.32 is used f = 1030Hz scores 3 marks}

QUESTION TOTAL = 8