Question Number	Answer	Mark
1 (a)	There is a change in density from water to air **Or** There is a change in light speed from water to air **(1)** This causes a change in direction of light (away from normal travelling from water to air) **(1)** So light appears to come from a different point of origin **(1)**	**3**
1 (b)	Use of refractive index = speed of light in air / speed of light in water **(1)** Speed of light in water = 2.26×10^8 m s^{-1} **(1)** <u>Example of calculation</u> $1.33 = 3.00 \times 10^8$ m s^{-1} / Speed of light in water Speed of light in water = 2.26×10^8 m s^{-1}	**2**
1 (c) (i)	Angle in water measured as 27° to 29° **(1)** Use of 1.33 × sin (angle in water) = 1.00 × sin (angle in air) **(1)** Angle in air calculated as 37° to 40° **(1)** <u>Example of calculation</u> 1.33 × sin (28°) = 1.00 × sin (angle in air) Angle in air = 38.6°	**3**
1 (c) (ii)	Ray drawn on diagram refracting away from the normal and extrapolated back **(1)** Label or other explanation that light appears to come from a different position (accept ray directed to an eye or stick in new position) **(1)**	**2**
	Total for question	**10**

Question Number	Answer		Mark
2(a)	Change in direction of wave (accept ray or any named wave) (do not accept bend) (Due to) change in (optical) density / speed / medium	**(1)** **(1)**	**2**
2(b)	There is no change in direction for the light (passing between the water and the gel) **Or** There is no refraction (as the light passes between the water and the gel) (accept … within the beaker) The light must have the same/similar wave speed in the water and gel (accept same/similar density for water and gel)	**(1)** **(1)**	**2**
2(c)	(When light strikes a boundary with) angle of incidence greater than the critical angle **Or** When light within a denser medium strikes a boundary with a less dense medium All of the light is reflected **Or** none of the light is transmitted **Or** none of the light is refracted	**(1)** **(1)**	**2**
2(d)(i)	Use of $\mu = \sin i / \sin r$ $x = 41(°)$ <u>Example of calculation</u> $\sin x = \sin 60° / 1.33$ $x = 40.6°$	**(1)** **(1)**	**2**
2(d)(ii)	Use of $\mu = \sin i / \sin r$ with $i = 90°$ (accept stating $\sin c = 1 / \mu$) $c = 49(°)$ <u>Example of calculation</u> $\mu = \sin 90° / \sin c$ $\sin c = 1 / \mu = 1 / 1.33$ $c = 49°$	**(1)** **(1)**	**2**
2(d)(iii)	Angle in gel < critical angle **Or** angle y < critical angle **Or** (If angle x = angle y, then this corresponds to an) angle in air of 60° Not total internal reflection so some light reaches screen **Or** Light will be refracted/transmitted so some light reaches screen	**(1)** **(1)**	**2**
	Total for Question		**12**

Question Number	Answer		Mark
3(a)	Calculates path difference = 12 (cm) Phase difference 0, 360° or 2π **Or** Calculates number of wavelengths in two paths Phase difference 0, 360° or 2π	(1) **(1)** **(1)** **(1)**	**2**
3(b)	Waves superpose **Or** interference between two waves takes place In phase constructive **Or** Antiphase destructive Links to <u>amplitude</u> maximum **Or** <u>amplitude</u> zero respectively In phase/constructive/max amplitude is where chocolate is hot with opposite at cold spots. **Or** Antiphase/destructive/min amplitude is where chocolate is cold with opposite at hot spots.	**(1)** **(1)** **(1)** **(1)**	**4**
3(c)	Coherent means a constant phase relationship (If the relationship not constant) a point could sometimes be constructive and sometimes destructive	**(1)** **(1)**	**2**
3(d)	Use of $c = f\lambda$ Calculates $c = 2.94 \times 10^8$ (m s^{-1}) **Or** λ = 12.2 (cm) **Or** f = 2500 (MHz) Sensible comment based on their calculated value. e.g. close to real value, so successful **Or** reference to uncertainty in data <u>Example of calculation</u> $c = 2.45 \times 10^9$ Hz × 0.12 m $c = 2.94 \times 10^8$ m s^{-1}	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Question Number	Answer		Mark
4 (a)	Measure angles of incidence and refraction (clear variants accepted or correct angles shown on a diagram)('*i*' and '*r*' accepted) Plots sin *i* vs sin *r* Correct gradient identified for their graph (assume sin *i* on *y* axis unless stated otherwise, assume statements using 'vs' or 'against' state *y* axis first) [If angle of reflection referred to instead of refraction, only allow 2nd mark] (Allow 3rd but not 2nd mark if *i* vs *r* and point from line used in μ = sin *i* / sin *r*)	**(1)** **(1)** **(1)**	**3**
4 (b)(i)	angle of incidence (for light travelling from denser medium) has angle of refraction of 90˚ (may refer to leaving along surface/boundary)	**(1)** **(1)**	**2**
4 (b)(ii)	Use of μ = sin *i* / sin *r* (accept stating sin *c* = 1 / μ) *c* = 49˚ (n.b. ue applies) <u>Example of calculation</u> sin *c* = 1 / μ = 1 / 1.33 *c* = 49˚	**(1)** **(1)**	**2**
	Total for question		**5**

Question Number	Answer		Mark
5 (a)	Refraction	**(1)**	
5(b)(i)	Normal correctly added to diagram *i* and *r* correctly labelled (consequent mark)	**(1)** **(1)**	**2**
5(b)(ii)	Greater refraction than the red light as light enters the raindrop (must be between red light ray and centre) Reflection followed by refraction away from normal as ray emerges from the raindrop.	**(1)** **(1)**	**2**
5(c)(i)	The angle of incidence (in the denser medium) for which angle of refraction is 90º **Or** angle of incidence for which a ray is transmitted along the boundary	**(1)**	**1**
5(c)(ii)	Use of sin *i* /sin *r* = μ with *i* = 90º **Or** sin *c* = 1/ μ c = 50º (N.B. missing º is a unit error) <u>Example of calculation</u> 1/sin c = 1.3 sin c = 1/1.3 c =50.3º	**(1)** **(1)**	**2**
5(d)	Substitution into $v = f\lambda$ $\lambda = 5.2 \times 10^{-7}$ m <u>Example of calculation</u> $\lambda = 2.2 \times 10^{8}$ m s^{-1} / 4.2×10^{14} Hz $\lambda = 5.2 \times 10^{-7}$ m	**(1)** **(1)**	**2**
	Total for question		**10**

Question Number	Answer	Mark
6(a)(i)	Greater refraction at the first face **(1)** Greater refraction at the second face **(1)** (accept new incident ray if parallel)	**2**
6(a)(ii)	Displacement/it increases with concentration **(1)** At increasing rate **OR** not linearly **(1)**	**2**
6(a)(iii)	Evidence that curved line has been drawn **(1)** Concentration 74 % - 76% (dependent mark) **(1)**	**2**
6(a)(iv)	Distance (between prism and screen) affects displacement/ Displacement would increase if the screen is moved away/ Displacement would decrease if screen moved nearer **(1)**	**1**
6(b)(i)	Polarised light is when the oscillations / vibrations (associated with the wave) are in one plane only **(1)** Plane includes direction of travel (of the wave). **(1)** **OR** Polarised light is when the oscillations / vibrations (associated with the wave) in one direction only, **(1)** (oscillations / vibrations are) perpendicular to the direction of travel (of the wave). **(1)**	**2**
***6(b)(ii)**	(QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) **Max 4** • Mention of polarising filter/Polaroid/polariser **(1)** • Rotation (of filter) until minimum/ maximum intensity (**not** rotation of solution) **(1)** • (Rotation) done with and without the sugar solution **(1)** • identifies correct difference in angles **(1)** • use of protractor/polarimeter **(1)**	**4**
	Total for question	**13**