3	**B is the correct answer** A is not correct because 1.33 should multiply the sin of the refracted angle in water C is not correct because the equation is inverted D is not correct because the equation is inverted and 1.33 should multiply the sin of the refracted angle in water	1

9	**The only correct answer is B** A is not correct because amplitude will decrease C is not correct because velocity will decrease D is not correct because wavelength will decrease	1

1	**The only correct answer is B (2.04×10^8 m s^{-1})** A is not correct because this is 47% of the speed of light in a vacuum C is not correct because this is the speed of light in a vacuum D is not correct because this is greater than the speed of light in a vacuum	1

3	**B is the correct answer** A is not the correct answer as this would reduce the detail C is not the correct answer as this would have no effect on detail D is not the correct answer as this would reduce the detail	**(1)**

2	**The only correct answer is B** A is not correct because it has an incorrect use of the factor of 2 C is not correct because it is an incorrect arrangement D is not correct because there is no factor of 2	1

10	**The only correct answer is C** A is not correct because reflection is the correct answer B is not correct because diffraction is not relevant in this context D is not correct because reflection is the correct answer	**1**

Question Number	Answer	Mark
9	**The only correct answer is C time between consecutive pulses is too short** The next pulse would be transmitted before the previous pulse is received	**1**
	***A** is not correct because it is not significant* ***B** is not correct because it is not significant* ***D** is not correct because it is not significant*	

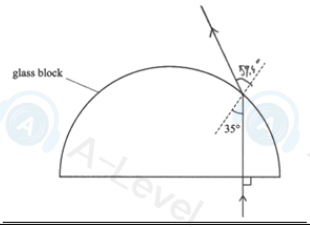
8	**D is the correct answer as 45° is beyond the critical angle, so total internal reflection takes place** A is not the correct answer as there will also be some reflection at this angle B is not the correct answer as there will also be some refraction at this angle C is not the correct answer as there will be no refraction at this angle.	**(1)**

6	**The only correct answer is D** $\left(\frac{340 \times 4 \times 10^{-3}}{2}\right)$ A is not correct because this doubles time or doubles distance B is not correct because this is an incorrect rearrangement C is not correct because this does not halve distance or time	**1**

	D - correct answer	
7	A - y and x are not the angle of incidence and angle of refraction respectively B - y and x are not the angle of incidence and angle of refraction respectively C - incorrect equation	**1**

Question Number	Answer		Mark
18a	Vibrations/oscillations in one plane which includes the direction of wave travel **Or** Vibrations/oscillations in one direction perpendicular to the direction of wave travel	(1) (1) (1) (1)	**(2)**
18b	The refracted ray lacks the planes of oscillation in the reflected light. **Or** the refracted ray has a plane of polarisation perpendicular to the plane of polarisation of the reflected light So, the refracted ray must also be partially plane polarised (MP2 conditional on awarding MP1)	 (1) (1)	**(2)**
18ci	See $n_a\sin\theta_a = n_g\sin\theta_g$ **Or** $n_a\sin\theta_B = n_g\sin r$ $n_a\sin(\theta_B) = n_g\sin(90 - \theta_B)$ **Or** $n_a\sin(\theta_B) = n_g\cos(\theta_B)$ **Or** $\sin r = \cos\theta_B$ sin (θ_B) divided by cos(θ_B) to give tan (θ_B) leading to answer	 (1) (1) (1)	**(3)**
18cii	Substitution of values into $\tan(\theta_B) = \frac{n_g}{n_a}$ $\theta_B = 56°$ **Example of calculation** $\tan(\theta_B) = \frac{n_g}{n_a}$ $\theta_B = \tan^{-1}(1.50 / 1.00) = 56°$	(1) (1)	**(2)**
18ciii	Refractive index (of glass) is greater for violet **Or** $\frac{n_g}{n_a}$ is greater for violet **Or** $\tan\theta_B$/ $\sin\theta_B$ /θ_B is greater for violet Clearly links one of the above to the student being incorrect.	 (1) (1)	**(2)**
	Total for question 18		**11**

Question Number	Answer		Mark
17(a)	Use of $v = \frac{s}{t}$ with $v = 3.00 \times 10^8$ ms^{-1}	(1)	
	Correct use of a factor of 2 (MP2 dependent upon awarding MP1)	(1)	
	$s = 39$ m	(1)	**3**
	Example of calculation $3.00 \times 10^8 \text{m s}^{-1} = \frac{2s}{2.6 \times 10^{-7}\text{s}}$ $s = \frac{3.00 \times 10^8 \text{m s}^{-1} \times 2.6 \times 10^{-7}\text{s}}{2} = 39$ m		
17(b)(i)	Any reference to a change in frequency/wavelength	(1)	
	When the truck slows down, this results in the car and truck moving closer together **Or** there is relative motion between the car and the truck	(1)	
	When the truck slows the (received) frequency is higher **Or** When the truck slows down the (received) wavelength is shorter	(1)	**3**
	(MP3 is dependent on awarding MP2)		
17(b)(ii)	The new car detects a decrease in speed more quickly (than the driver of a conventional car) **Or** the new car applies the brakes more quickly (than the driver of a conventional car)	(1)	
	The new car has negligible reaction time **Or** the conventional car (driver) has greater reaction time	(1)	
	So the new car maintains its distance from the vehicle in front **Or** the thinking/stopping distance is less	(1)	**3**
	Total for question 17		**9**

Question Number	Acceptable Answer		Additional Guidance	Mark
14(a)	The incident ray is perpendicular to the surface of the glass block **Or** Ray is incident along the normal to the surface **Or** Angle of incidence = 0(°)	**(1)**	Allow wavefronts parallel to surface of glass block	**1**
14(b)(i)	Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\theta = 59°$	**(1)** **(1)**	Example of calculation $1.5 \sin 35° = \sin\theta_2$ $\theta_2 = 59.35°$	**2**
14(b)(ii)	Ray refracts on correct side of normal and angle consistent with (b)(i)	**(1)**	Example of diagram 	**1**
14(c)	Use of $\sin C = \frac{1}{n}$ Use of trigonometry to calculate distance from centre to ray Adds radius of block to distance from centre x = 75 mm	**(1)** **(1)** **(1)** **(1)**	Example of calculation $\sin C = \frac{1}{1.5} = 0.67$ $0.67 = \frac{\text{distance from centre to ray}}{45 \text{ mm}}$ $0.67 \times 45\ mm = 30.3$ mm (if left as a fraction calculation gives 30.0 mm) $x = 45 + 30.3 = 75.3$ mm	**4**