2021 ASSESSMENT REPORT

PHY415115 - PHYSICS

General Comments

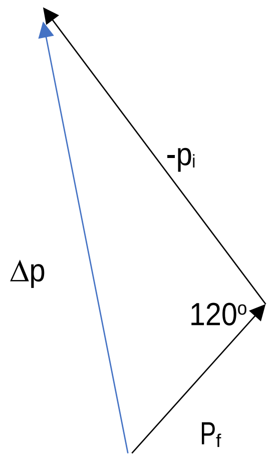
Criteria 5 and 6 were generally done well, with students performing strongly and scoring high marks, largely due to the lack of complex vector question in C5 and the lack of emphasis on direction in C6. Criterion 7 was more challenging due to the focus on polarisation and refraction, and students generally performed less well in this section. Criterion 8 had a wide range of marks, in contrast to last year, perhaps indicating that some students were pressed for time.

The cut-offs used for each criterion (out of 40 except where noted) are the following:

Criterion	Min C	Min B	Min A
5	14	26	34
6	13.5	26.5	35
7	12	23.0	30.5
8	12	26.0	34

Note: This criterion was marked out of 38 due to the removal of question 16 (b).

Criterion 5 – Part 1

C5	Answer	Marking Guide	Marker's Comment
Question 1			
(a)		$\Delta p = p_f - p_i$ or $p_f = p_i + \Delta p$ or velocity equivalent acceptable. Max 1.5 for labelled addition triangle Max 2 if 120 is incorrect. Diagram must include vectors (triangle not sufficient).	Students should be encouraged to write a vector statement before drawing a vector diagram. Many students' vector diagrams incorrectly showed $\Delta p = p_i + p_f$
(b)	$-p_i = 0.055 \times 3$ kgms^{-1} $= 0.165$ kgms^{-1} $p_f = 0.055 \times 2.5$ kgms^{-1} $= 0.138$ kgms^{-1} Using cosine rule:	Calculations must be consistent with their vector diagram. 1 for use of p=mv calculation with unit	Cosine rule was used effectively by most students.

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	$\Delta p =$ $\sqrt{0.165^2 + 0.138^2 - (2)(0.165}$ = <u>0.263 kgms^{-1}</u> Because the mass doesn't change, an alternative is to look at change in velocity only, then multiply by mass. $\Delta v =$ $\sqrt{3.00^2 + 2.5^2 - (2)(3.0)(2.5)}$ = 4.77 m s^{-1} hence Δp = 0.055 x 4.77 = <u>0.263 kgms^{-1}</u>	1 for an appropriate method (components or cosine rule) 1 for final answer	
(c)	Hence size of force = $\Delta p/t$ = 0.263 / 0.01 = <u>26.3 N</u>	1	
Question 2			
(a)	200 kmh^{-1} = 55.6 ms^{-1} Vertical component = 55.6 sin 11° = 10.6 ms^{-1} horizontal component = 55.6 cos 11° = 54.0 ms^{-1}	0.5 for each component 0 if swapped around but ECF in following parts	No marks deducted if done in km/h.
(b)	On flat land s = 0 = ut + ½ at^2 so t = 0 or t = 10.6 10.6/1.86 = 5.70 s	1 for an appropriate method 1 for correct answer (in seconds) Appropriate methods: displacement = 0 or final v = 0 and double time -1 if used u in km/h in this part.	Students should be encouraged to provide an annotation with their calculation. For example: Total time of flight = time up * 2
(c)	Horizontal displacement travelled = 5.70 x 55.6 cos 11° = <u>311 m</u>	1 Evidence of $s=u_xt$ used correct using answers from a and b	
(d)	The time above the ground depends on gravitational acceleration (t = 2u/a) and Mars has about 1/3 the gravity of Earth. The ball is therefore in the sky for about 3 times longer than on Earth. Therefore, the ball goes about 3 times further horizontally ignoring the effects of the air on a golf ball. (Horizontally $s = u_H t$)	1 for some mention of increased time of flight / decreased gravity 1 for some correct justification or reference to some relevant equations or relationships	
Question 3			
(a)	$F_1 = m_1\Delta v_1 /\Delta t$ Newton's 2nd Law	1	Marker discretion for all of a, b, and c.
(b)	$F_2 = m_2\Delta v_2 /\Delta t$ Newton's 2nd Law	1	
(c)	$F_1 = - F_2$ Newton's 3rd Law	1 Max 0.5 for $F_1 = F_2$	

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(d)	From c) $m_1\Delta v_1 / \Delta t = - m_2\Delta v_2 / \Delta t$ Hence $m_1\Delta v_1 = - m_2\Delta v_2$ That is change of m_1 momentum = - change of m_2 momentum thus $m_1\Delta v_1 + m_2\Delta v_2 = 0$ $\Delta p_1 + \Delta p_2 = 0$ so the TOTAL change in momentum = 0. If the total change is zero then momentum must be conserved.	1 for changing forces to momentum 1 for argument that total change in momentum is zero therefore momentum is conserved, in words or equations -0.5 if no final statement / conclusion showing $\Delta p_{tot}=0$ (subject to marker discretion)	Many students used $F_1 = F_2$ as the starting point here. This resulted in a statement that $\Delta p1 = \Delta p2$ which does not imply conservation of momentum. Many students included the statement p1 = p2, showing that they did not understand the significance of the Δ symbol.
Question 4			
(a)	Minimum force up must equal the weight of Ingenuity. Thus, minimum force = mg = 1.80 x 3.72 = <u>6.70 N down</u>	1 for justification (relating to weight force) 1 for answer	This was answered well by most students. The main error was to use the acceleration due to gravity on Earth (rather than Mars) when calculating the weight (part marks were given).
(b)	F = 6.70 = Δmv / t so Δm /t = F/v = 6.70 /17.2 = <u>0.39 kgs^{-1}</u> Alternatively: A solution based on the value 2 x 10^{-2} kg m^{-3} for the density of Mars air uses $V = \pi r^2 h = \pi \times 0.6^2 \times 17.2 = 19.4\ m^3$ So, using mass = density x V = 0.02 x 17.2 = <u>0.390 kg s^{-1}</u>.	1 for a correct approach 1 for answer	This was answered reasonably well by students. The preferred approach was to calculate the mass of the cylinder of air displaced by the rotors each second, although the answer could also be determined through calculating change in momentum. Some students simply multiplied the density of air by its velocity, neglecting cross-sectional area. These students were awarded 0.5 marks.
(c)	Work done per second = E_K gained by 0.39 kg of air = $1/2mv^2$ = <u>57.7 J</u> <u>57.7 / 1 sec = 57.7 W</u>	1 final answer including units (J or W accepted)	This question caused some difficulty for students with many attempting to calculate work done through W = Fs cosθ and running into trouble.
(d)	Total energy available = Power x t = 350 x 90 = <u>3.15 x 10^4 J</u>	1	This was answered very well by most students.
(e)	Percentage energy = 57.7 x 90 x 100 / 350 x 90 = <u>16.5%</u>	1	This was answered very well by most students. Some students forgot to multiply by 100 when

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			obtaining the percentage and were awarded part marks.
Question 5			
(a)	Speed of the Moon = circumference / period = $2\pi r$ / T = 2 x π x 3.84 x 10^8 / 27.3 x 24 x 3600 = 1.02 x 10^3 ms^{-1} centripetal acceleration = v^2 /r = 1.05 x 10^6 / 3.84 x 10^8 = 2.72 x 10^{-3} ms^{-2}	1 for finding T in s 1 for appropriate method 1 for final answer	This was answered well by most students. A significant number of students failed to square the period, T, when calculating the acceleration and were awarded part marks.
(b)	$g = GM/r^2$ so $g_1/g_2 = r_2^2/r_1^2$ with a common mass M for r_1, r_2 So g at Moon orbit = 9.81 x (6.37 x 10^6 /3.84 x 10^8)^2 = 2.70 x 10^{-3} Nkg^{-1} This is almost identical to the answer of a)	1 for use of $1/r^2$ or law of gravitation 1 for attempt at calculation involving ratio of radii or other relevant calculation 1 for showing values are similar	This question was poorly answered by many students. This question was often left blank or answered by writing a number of formulae in the space. Students who made some progress using either ratios or Kepler's law were awarded part marks.
(c)	$g = GM/r^2$ so $M = gr^2 / G$ = 9.81 x (6.37 x 10^6)^2 /6.67 x 10^{-11} = <u>5.97 x 10^{24} kg</u>	1 for use of correct equation (Kepler or grav field strength) 0.5 for rearranging correctly 0.5 for correct substitution (particularly radius) 1 for correct answer	This question was very well answered. Mistakes were generally a result of errors in calculator use. If substitution is correct but answer is wrong without evidence of correct rearrangement - maximum 1.5 mark Some evidence of working required. Just numerical answer without any working is 1 as number is provided in Q6.
Question 6			
(a)	At the point P $g_E = GM_E/r_{EP}^2$ = 6.67 x 10^{-11} x 5.97 x 10^{24} / (3.46 x 10^{11})^2 = 3.33 x 10^{-3} N kg^{-1} towards Earth $g_M = GM_M/r_{MP}^2$ = 6.67 x 10^{-11} x 7.34 x 10^{22} / (0.38 x 10^{11})^2 = 3.38 x 10^{-3} N kg^{-1} towards Moon	1 mark for calculating field strength of either correctly 1 mark for subtracting the field strengths from each other 1 mark for final answer	This question was reasonably answered by students. The most significant error was to calculate force rather than gravitational field strength. Another error was to use insufficient significant figures during the intermediate calculations; this resulted in a net field strength of zero at point P.

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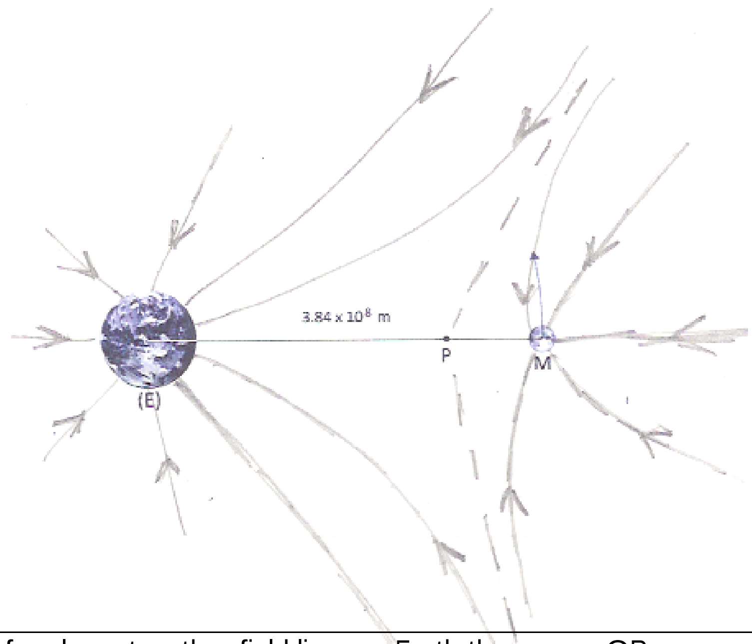
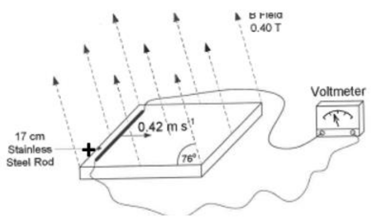
	$g = g_M + g_E = 3.38 \times 10^{-3} - 3.33 \times 10^{-3} = 0.05 \times 10^{-3}$ Nkg towards Moon		
(b)			This question was generally answered poorly with only a few students awarded full marks. However, a fascinating, and creative, range of options were presented. Part marks were awarded where students recognised that the gravitational field lines were directed towards the Earth and the moon and/or where they showed that the density of field lines near the Earth was greater than the density of field lines near the moon.
	1 for closer together field lines on Earth than moon OR more field lines ending on Earth than moon 1 for field lines inwards to both planets 1 for general shape		

Criterion 6 – Part 2

C6	Answer	Marking Guide	Marker's Comment
Question 7			
(a)	Emf = vlB sinθ = 0.42 x 0.17 x 0.4 x sin 76° = <u>0.027 volts</u>	1 for any attempt to use emf = vlB (with correct units) 1 for correct answer -0.5 for any incorrect substitution (angle, length not in m) or no unit (to max of -1)	Parts a and c were done reasonably well by most students. Errors with the angle were most common.
(b)	End "nearest" is positive 	Accepted: - Labelling correct conventional current - Positive on voltmeter - Negative end shown correctly	Many students got the correct side as positive.
(c)	The current is flowing in the wire in B so:	1 for use of correct formula 0.5 for answer and units 0.5 for direction	Done reasonably well by most.

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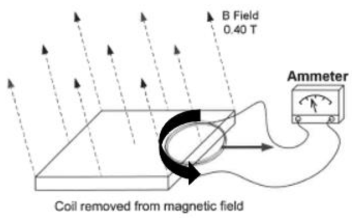
C6	Answer	Marking Guide	Marker's Comment
	$F_B = IlB \sin\theta$ = 0.045 x 0.17 x 0.4 x sin 76° = <u>0.0030 N to the left</u>	ECF if incorrect angle or length repeated	
(d)	If it is moving at the same speed then the Emf will remain the same as earlier. But Emf = IR. For the fixed EMF, lower resistance means larger current. A larger current means that the value of $F_B = IlB \sin\theta$ must necessarily be larger. Work and energy explanation also acceptable	0.5 for same without explanation 1 for an answer which contains some correct justification with reference to current, resistance or EMF 2 for full answer including reference to emf, resistance, current and force	Mixed answers. A few students commented that the EMF would not change but the lowered resistance leads to a greater current by Ohm's Law. Part c guarantees that the force will be larger with the larger current.
(e)	From Lenz's law, the induced B field is up as the field in to coil is getting weaker so the current is anticlockwise OR the back section of the coil will have a PD induced across it as it is a conductor being pulled through the field. The section closest to the viewer will be positive. As part of the loop is out of the field, a current will now circulate anticlockwise. 	Diagram: • 1 for labelling current on diagram correctly Explanation: • 1 for reference to Lenz's law • 1 for applying Lenz's law correctly to the situation	Answers were confused and hard to interpret. Many mentioned Lenz's Law but few quoted it correctly.

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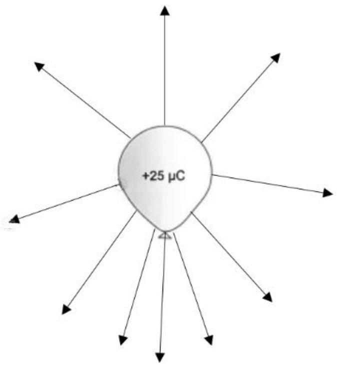
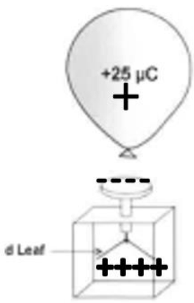
C6	Answer	Marking Guide	Marker’s Comment
Question 8			
(a)	Friction with dust, air molecules	1 for any reasonable answer	Most gave a reasonable answer.
(b)		0.5 for rough symmetry of field lines 0.5 for direction correct	Most recognised the E Field around a sphere.
(c)	Treating the balloon as a sphere, $E_E = kQ/r^2 = 9 \times 10^9 \times 25 \times 10^{-6} / 1.5^2$ $= \underline{9.74 \times 10^4 \text{ N C}^{-1}}$ outwards	0.5 correct formula 0.5 correct answer	This was generally well answered.
(d)	The electroscope is neutral in overall charge. Bringing the balloon near attracts negative charge to the top of the electroscope leaving the leaves positive so they open as a response to the mutual repulsion of like charge. 	Diagram: 1 for diagram showing separation of charge Explanation: 1 for electrons attracted to balloon 1 for positive gold leaves repel	Many students gave incorrect answers. A large number failed to recognise the electrons are the charges that move in a metal.

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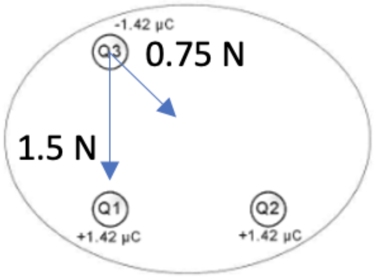
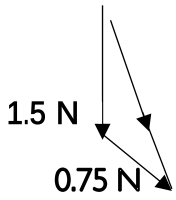
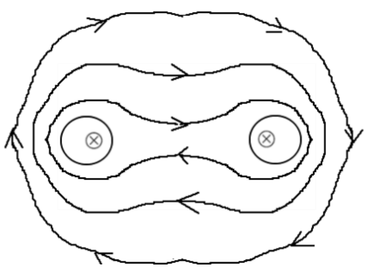
C6	Answer	Marking Guide	Marker's Comment
(e)	Touching the electroscope with the balloon will lead to a transfer of charge between the two so the electroscope will now have an imbalance of charge. When the balloon is removed the electroscope will now have a positive overall charge and the leaves will remain apart.	1 for correctly justified change	This question was poorly answered. Students failed to recognise that the overall charge on the electroscope would now be positive so the leaves would open.
Question 9			
9a 3	Coulomb's Law $F_{3,1} = 9 \times 10^9 \times (1.42 \times 10^{-6})^2 / (0.11)^2 = 1.5$ N The triangle is a $1:1:2^{1/2}$ hence the distance between Q2 and Q3 is $2^{1/2}$ greater than between Q3 and Q1 OR: use Pythagoras to find distance from Q2 to Q3 is 0.1556m Hence $F_{2,3} = F_{3,1} / (2^{1/2})^2 = 1.5/2 =$ <u>0.75 N</u>	Cumulative marks as follows: 1 for using Coulomb's law 1 for converting units and correct substitutions 0.5 for each answer correct	This was answered well by most students. The most common approach was to calculate the distance from Q2 to Q3 using Pythagoras' Theorem, followed by a separate Coulomb's Law calculation using that distance.
9b 1		Cumulative marks as follows: 0.5 for both point away from Q3 towards Q1 and Q2 0.5 for relative magnitudes	This question was poorly answered by many students. Relatively few were able to establish the correct directions for the forces <u>and</u> draw them to scale. Some students drew the forces exerted on Q1 and Q2 by Q3.

C6	Answer	Marking Guide	Marker's Comment
and 9c 2	Vector add the two forces  Angle between forces is 135° so using the cos rule $F = (1.5^2 + 0.75^2 - 2 \times 1.5 \times 0.75 \cos 135^\circ)^2$ = <u>2.10 N</u>	Total marks as follows: 0.5 for addition of magnitudes 1 for attempted 2D addition using 90-degree triangle 1.5 for correct method (either vector triangle and cosine rule OR components) and answer using an incorrect angle 2 for correct method and answer	Relatively few students received full marks for this question. Many attempted either scalar addition of magnitudes or used Pythagoras' Theorem for a 2D addition. Students who recognised the need for a components or cosine rule approach often used an incorrect angle.
Question 10			
(a)	$F_B = k\, I_1 I_2 l / r$ $= 2 \times 10^{-7} \times 15^2 \times 5 / 0.016$ = <u>0.014 N</u>	Cumulative marks as follows: 0.5 for correct formula 1 for correct substitutions 0.5 for correct answer With: -0.5 for squaring 0.016 -0.5 for not including 'x 5'	This question was answered well by most students. Common errors were squaring the distance, halving the distance or ignoring the length.
(b)	Attract	Total marks as follows: 0.5 for incorrect answer based on a valid justification 1 for correct answer	This question was answered incorrectly by a surprising number of students. Part marks could not be awarded in most cases, due to lack of explanation or justification.
(c)		Cumulative marks as follows: 1 for arrows in correct direction (around each wire individually) 1 for general shape (envelope around both wires) With: -0.5 for crossed field lines -0.5 for glaring asymmetry Proximity of field lines was ignored in marking.	A surprisingly small number of students received full marks for this question. The majority correctly indicated the circular field lines around each current, but relatively few included the larger field around both currents.

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C6	Answer	Marking Guide	Marker's Comment
(d)	At the point Z Flux density of Left-hand current is $B_1 = 2 \times 10^{-7} \times 15 / 0.12$ T down $= 2.5 \times 10^{-4}$ T down Flux density of Right-hand current is $B_2 = 2 \times 10^{-7} \times 15 / 0.004$ T up $= 7.5 \times 10^{-4}$ T up Total flux density = $\underline{5 \times 10^{-4}\ \text{T}}$	Cumulative marks as follows: 1 for using correct formula 1 for correct values of B_1 and B_2 1 for subtraction and final answer	This question was answered well by most students.
(e)	At this point using $r = mv/qB$ $= 1.67 \times 10^{-27} \times 7 \times 10^4 / 5 \times 10^4 \times 1.6 \times 10^{-19}$ $= \underline{1.46\ \text{m}}$	Cumulative marks as follows: 0.5 for correct formula 1 for correct substitutions 0.5 for final answer With: -0.5 for incorrect mass -0.5 for incorrect charge	This question was answered well by most students. Common errors included the use of the mass of an electron instead of a proton, and the use of '1' for charge instead of a single elementary charge. A surprising number of students worked from basic principles ($F_B=F_C$) rather than using the radius formula directly.
Question 11			
(a)	$E = V/d = 150 / 0.01 = \underline{1.5 \times 10^4\ \text{N C}^{-1}}$	Cumulative marks as follows: 0.5 for formula 0.5 for answer With: -0.5 for missing units (NC^{-1} or Vm^{-1})	This question was well answered by a most students.
(b)	$F = qE = 2 \times 1.6 \times 10^{-19} \times 1.5 \times 10^4 = \underline{4.8 \times 10^{-15}\ \text{N}}$	Cumulative marks as follows: 0.5 for formula and correct charge 0.5 for final answer With: -0.5 for magical invocation of 'x2', unrelated to charge	This question was answered well by most students.
(c)	accel $a = F / m = 4.8 \times 10^{-15} / 6.64 \times 10^{-27} = 7.23 \times 10^{11}\ \text{m s}^{-2}$ Alpha travels vertically a distance of 0.5 cm so time to hit the plate Using $s = ½ at^2$	Cumulative marks as follows: 1 for acceleration 1 for time 1 for distance With: -0.5 for minor errors in any of these	Most students received 1.5 or 2 marks for this question, but a smaller proportion received full marks. Most were able to determine acceleration and deduce a final distance based on time, but fewer

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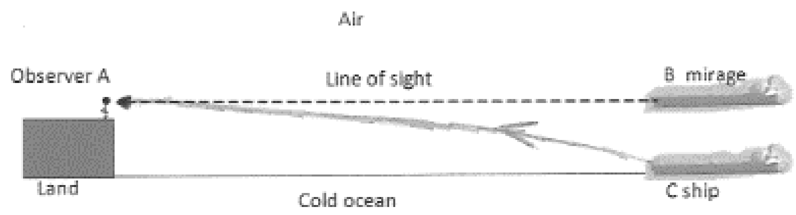
C6	Answer	Marking Guide	Marker's Comment
	0.005 = ½ 7.23 x 10^{11} t^2 t = 1.18 x 10^{-7} s Horizontal distance travelled = 5 x 10^6 x 1.18 x 10^{-7} = <u>0.588 m</u>		were able to correctly determine the time. Marks were also awarded for an energy-based approach to finding final vertical velocity, although this approach very rarely succeeded.
(d)	This is a velocity filter situation v = E/B so B = E/v = 1.5 x 10^4 / 5 x 10^6 = <u>3 x 10^{-3} T</u> The force on the alpha by E is up so the force by B must be down. By RHR <u>B has a direction out of the page</u>	Cumulative marks as follows: 1 for magnitude 1 for direction	Relatively few students received full marks for this question. Most appeared to have understood the velocity filter scenario but failed to subsequently move from the notion of balanced forces to the relationship between fields. Many stated the magnitude and direction of the required magnetic force. A surprising number of successful students worked from basic principles (F_B=F_E) rather than using the velocity filter formula directly. Part marks could not be awarded in most cases due to lack of explanation or justification.

Criterion 7 – Part 3

C7	Answer	Marking Guide	Marker's Comment
Question 12			
(a)			A number of students thought this was a total internal reflection situation and showed the light bouncing between the ocean and the line of sight; these students received no marks.

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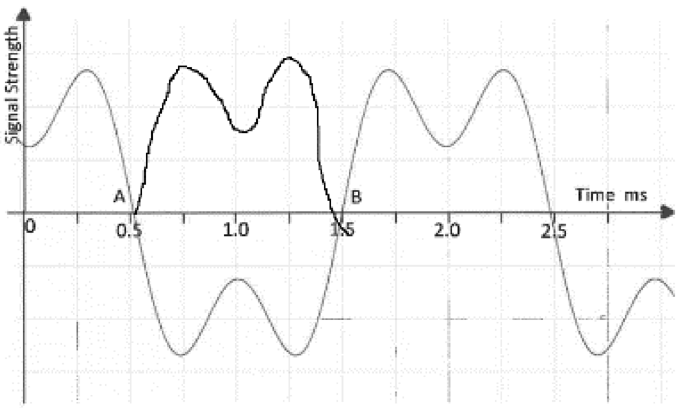
C7	Answer	Marking Guide	Marker's Comment
	0.5 for line showing some refraction in either direction 1 for any line coming in to A along the line of sight 1 for correct curvature. 0 for straight line Full marks for line with single point of refraction in right direction rather than curved.		
(b)	At any point, if a normal is drawn to the horizontal across the ray AC's path, the refracted angle is larger than the incident angle hence the refractive index is dropping with distance from the water.	1 for refractive index is decreasing 2 for decreasing with explanation saying light is bending away from normal or towards boundary, discussion of velocity ratios, or showing with Snell's law ECF from part (a) if light bent the wrong way	No specific mention of Snell's law is required, a discussion of velocity ratios or direction of refraction was sufficient. Many student answers were not consistent with their diagrams in part (a).
(c)	The cooler air is nearer the water, so it follows that <u>cool air has a higher refractive index</u> than warmer air.	1 for correct relationship ECF from part (b) if said n was rising.	Many students got this question correct despite incorrectly answering the previous part by looking at this based on air density and speed.
Question 13			
(a)			Generally done well.
	2 marks for correct line 1 mark if line is sloppy / imprecise and does not approximately mirror the noise wave		

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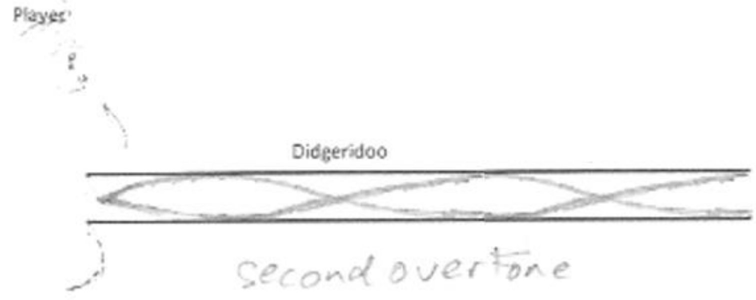
C7	Answer	Marking Guide	Marker's Comment
(b)	Superposition	1 for superposition 0.5 for interference	A surprising number of students were not able to name the principle of superposition. Answers that used 'destructive interference' received half marks; whilst this is the effect of the superposition of the two waves, it is not the principle used to sketch it.
(c)	The period of the wave is from 0.5 to 2.5 ms so the period is 2 ms. It follows that the frequency f = 1/T = 1/0.002 = <u>500 Hz.</u>	1 for finding period 1 for converting to f (ECF for frequency calc if period wrong) 1 if not use milliseconds (0.5Hz) 1 for incorrect selection of T but thorough working to get freq.	Alternate period of 0.5 ms (period of small wave) (2000Hz) acceptable if working shown correctly. This question was poorly answered and many students used the wrong period from the graph and / or failed to realise it was in milliseconds.
Question 14			
(a)	The pipe is open at both ends so for the fundamental frequency; the corresponding wavelength is twice the pipe length. λ = v/f = 344 / 160 = 2.15 m, hence pipe length is ½ x 2.15 = <u>1.08 m</u>	1 for λ = 2l 1 for wave equation	Generally done well.
(b)	The pipe is now closed at one end. The pipe length is now = ¼ wavelength λ = 4 x 1.08 = 4.32 m Hence new fundamental frequency is 344 / 4.32 = <u>79.6 Hz</u>	1 for λ = 4l 1 for wave equation	Generally done well.
(c)			Many students drew the first overtone (the third harmonic).

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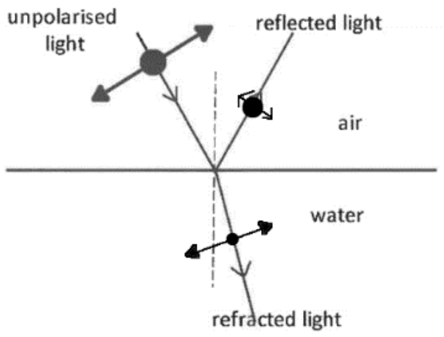
C7	Answer	Marking Guide	Marker's Comment
	1 for any shape which had an antinode at right and node at left (i.e., fundamental or first overtone) 2 for correct shape		
(d)	It is not possible to have a fourth harmonic as it is closed at one end – possible harmonics are 1^{st}, 3^{rd}, 5^{th}, ... Reason only odd multiples of quarter wavelengths can fit the pipe as the fixed end is a node while the open end is an antinode as far as motion of the air molecules is concerned – the molecules cannot move against the fixed and but can easily move at the open end.	1 for not possible 1 for justification with reference to boundary conditions or nodes / antinodes at ends ECF from part c if open tube drawn	Many students simply stated even harmonics were not possible for a closed ended tube and only got one out of two. Reference to nodes / antinodes at ends was required for full marks.
Question 15			
(a)		1 for dots and arrows on both rays, which attempts to show polarisation. 1.5 if shown with dots and crosses as fully polarised (no arrows on reflected ray, no dots on refracted ray). 1.5 if polarisation shown correctly but with arrows not perpendicular to ray. 2 for correctly showing longer arrows on refracted ray, shorter arrows on reflected, arrows perpendicular.	This question was poorly answered by most students. Many students are clearly unfamiliar with the dots and crosses convention for polarisation, and few could use it correctly to show relative intensities of different components.
(b)	The reflected light from the surface of the water is strongly polarized. As the lenses of the sunglasses are filters allowing vertically polarized light through, the reflections are blocked.	1 mark for saying it blocks glare / reflections by filtering polarized light 2 marks for reference to horizontally-polarised reflections OR plane of polarisation off the water compared to sunglasses	Most students had some understanding of polarising lenses acting as filters, although many explanations were poor and / or misleading in the way they were worded. Some recognition that the reflected light is polarized in a different direction to the filters needed for full marks.

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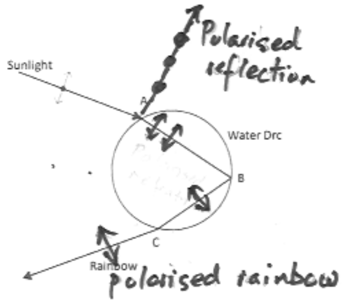
C7	Answer	Marking Guide	Marker's Comment
(c)	Reflections from shop front windows would be vertically polarized as the glass is vertical. The sunglasses would allow this plane through due to the lenses analyzing properties.	1 for recognizing reflections would be vertically polarized OR polarised in a different direction to the water 2 for linking this to the conclusion	Many students were unfamiliar with the fact that the reflected light is polarized parallel to the reflecting surface, which limited their ability to answer this question.
(d)	 At point A, much of the dot component will be reflected from the water surface so more of the arrow component than the dot component would enter the drop of water. This implies the light is already highly polarized when in the water both at B and C. The light leaving at C will therefore be polarized and so should be detectable by the sunglasses. (**Note: the direction of polarization of rainbows varies around the arc so the whole rainbow would not be visible through polarizing glasses)	1 for identifying there would be some polarisation 2 for explaining that the light is polarised at a boundary	This question was poorly answered. Students were awarded some marks for recognizing that the rainbow light would be polarised (regardless of direction) and better answers attempted to explain this polarization in terms of the reflection and / refraction of light through the raindrop. Students who attempted to explain by linking to the rainbow colours usually received no marks.
Question 16			
(a)	The single slit ensures the light on the double slit is <u>coherent</u> so the emissions from each of the double slits occur in phase.	1 for mention of one of: - diffraction OR so you can see the pattern - coherence - sources in phase light from double slit 2 marks for two of these three	Generally, most students were awarded some marks although many did not provide enough detail for a two mark question. Weaker responses suggested the slit created a beam of light and got no marks. Note the single slit does not make the light monochromatic or filter out a specific frequency or wavelength; these responses were not awarded marks.

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C7	Answer	Marking Guide	Marker's Comment
(b)	At the double slit $\sin\theta$ = Path Difference / S_1S_2 In the larger triangle double silt to screen, close enough $\sin\theta = YY_0 / x$ So Path Difference / $S_1S_2 = YY_0 / x$ That is $PD / d = YY_0 / x$ So $PD = YY_0\, d / x$	Not marked due to error in question – no mark allocations.	As there is an error in the question (there is no point A) this question was not marked. It may be used as discriminator for borderline papers. Markers also note that the derivation of this formula by relating the two similar triangles is beyond the scope of the course.
(c)	$W = \lambda x / d = 586 \times 10^{-9} \times 2 / 50 \times 10^{-6}$ = <u>0.0234 m</u>	0.5 for SI conversion 0.5 for use of correct equation 0.5 for substituting into correct locations 0.5 for correct answer with units	Generally done well by most students.
(d)	The 390 nm as it makes <u>W smaller so more dots</u>!	0.5 for correct choice 0.5 for justification	Generally done well.
(e)	The slits themselves individually make **single slit diffraction** patterns. As S_1 and S_2 are the same, their patterns sit on top of each other. The resulting total pattern is the double slit pattern multiplied by the single slit pattern.	1 for single slit diffraction / single slit pattern / single slit interference 1 for diffraction 0 for interference	No explanation needed. Some students attempted to explain the presence of dark spots and light spots but did not identify the specific effect causing this.
Question 17			
(a)	As per figure the light is going from the water to the observer. At Q, the angle to normal can be deduced $90 - 30 = 60^0$ thus the angle of incidence can be found through Snell's Law. $n_1 \sin\theta_1 = n_2 \sin\theta_2$ $1.33 \times \sin\theta_1 = 1 \sin 60^o$ gives $\theta_1 = 40.6^0$ = angle SPQ (not required)	1 for any attempt using Snell's law 0.5 for correct substitution (including correct angle) 0.5 for final answer of 40.6º No deduction for incorrectly finding angle SPQ after finding angle of 40.6 º correctly.	Many students failed to draw a normal to the interface and thus identify that the known angle is 60 rather than 30. Many students inadvertently reversed the direction of the light (no marks were lost for this).
(b)	$\tan 40.6^0 = SQ / 1$ so $SQ = 0.860$ m Also solvable with Sine Rule	1 for correct 0.5 if incorrect angle used from (a) and marks not already deducted. ECF if marks already deducted in (a).	This was essentially a geometry problem and done well by most students.

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C7	Answer	Marking Guide	Marker's Comment
(c)	SP' / 0.860 = tan 30° so <u>SP' = 0.50 m</u> Also solvable with Sine Rule	1 mark for using 30° 1 mark for solving with tan	This was essentially a geometry problem and done well by most students.
(d)	The bottom of the pond looks much closer to the surface than it really is!	1 mark for any reasonable answer	Any mention of apparent depth lower / water shallower was acceptable. Done well.

Criterion 8 – Part 4

C8	Answer	Marking Guide	Marker's Comment
Question 18			
(a)	Electrons in the current have sufficient energy to push atomic electrons to higher energy levels. These then descend to the lower empty levels emitting spectral photons.	0.5 for electrons promoted / ionized 0.5 for electrons falling energy levels	This question was answered well.
(b)	Using E = hf = $4.14 \times 10^{-15} \times 6.17 \times 10^{14}$ = <u>2.55 eV</u>	0.5 for correct answer in J 1 for correct answer in eV	This question was answered well. Some confusion on which value of h to use.
(c)	The transition n = 4 to n = 2 is 12.77 – 10.21 = 2.56 eV so the level <u>n = 4 to n = 2</u> is the transition.	1 for answer	This question was answered well. Some care required in matching the value in (b) to the difference in the two lines. Error carried forward (ECF) if students stated there is not transition which matches their eV from b.
(d) (i)	A photon of 12.5 eV does not correspond to a transition so it cannot be absorbed by the gas. <u>Nothing happens.</u>	1 for nothing happens	No explanation necessary.
(d) (ii)	An electron of 12.5 eV can cause an atomic level electron at ground level to rise to either the n= 2 or n = 3 levels so subsequently <u>3 photons can be emitted</u>, 10.21 eV, 12.11 eV and 1.90 eV	0.5 electron promoted 0.5 specifying levels No mention of photons required, although could also discuss electron falling and photons for 1 mark.	(i) and (ii) answered well. Some students got answers reversed or gave the same answer for both. These were awarded 0 marks.

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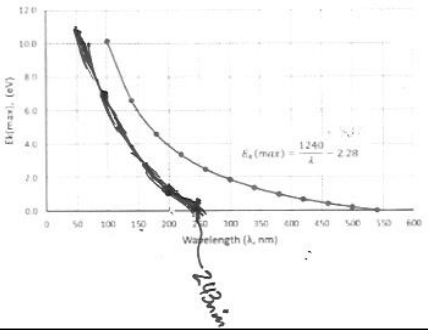
C8	Answer	Marking Guide	Marker's Comment
Question 19			
(a)	$E_{K\,(max)} = hf - W$ $= hc/\lambda - W$ $= 1240 / \lambda - W$ (note the wavelength is in nm, h in eV units) Thus, the work function W is <u>2.28 eV</u>.	1 for 2.2 – 2.3 eV from calculating from the wavelength intercept Or 1 for 2.28 eV from equation	Well answered. No reasoning needed.
(b)	Substituting in the graph formula, the $E_{K\,(max)}$ at 200 nm = $1240 / \lambda - 2.28$ $E_{K\,(max)} = 1240 / 200 - 2.28 = 3.92$ eV so PD to zero the current (the Stopping Voltage) = 3.92 volts	1 for approx. 4 eV ECF from part a	Not many successfully used the equation. Many estimated approximately 4eV from the graph for 0.5 marks
(c)	Photons of wavelength 550 nm when substituted in the above equation gives $E_{K\,(max)} = 1240 / \lambda - 2.28$ $= 1240 / 550 - 2.28 = 2.25 - 2.28$ $= -0.03$ eV <u>The photons have insufficient energy to eject the electrons.</u> OR from the graph, the wavelength intercept is 540 nm so no photoelectrons are ejected at 550 nm.	1 for mention of threshold frequency / wavelength 2 marks for linking this to energy and / or work function 1 for calculations without explanation	Well answered. Many students mentioned threshold frequency without linking to energy.
(d)	<u>No change to the graph</u> - more photons simply changes the size of the photo- current but not the energy range of the photoelectrons ejected which is a function of the metal structure.	1 for no change	Well answered
(e)	When $E_{K\,(max)} = 0 = 1240 / \lambda - 5.10$ then $\lambda = 1240 / 5.10 = 243$ nm therefore x- intercept = 243 nm  	1 for new x-intercept (labelled or approximate location correct) 1 for general shape tending vertical	Very few students labelled the intercept even though many calculated this correctly. A second point aided the correct shape of the graph. Common error was the graph tending to y axis.

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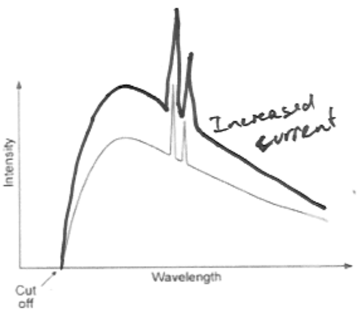
C8	Answer	Marking Guide	Marker's Comment
Question 20			
(a)	Number of atoms of Pu- 238: $N = nN_A = mN_A / M$ $= 4.23 \times 10^3 \times 6.02 \times 10^{23} / 238$ $= 1.07 \times 10^{25}$ atoms $A = 0.693\ N / T_{1/2}$ $= 0.693 \times 1.07 \times 10^{25} / 87.7 \times 365 \times 24 \times 3600$ = $\underline{2.68 \times 10^{15}\ Bq}$	1 for correct N 1 for decay constant (or manipulating equations) 1 for correct answer 3 for correct final answer without working	Many students missed one or both necessary conversions.
(b)	$A/A_0 = e^{-\lambda t} = 0.734$ $\ln(0.734) = -0.693\ t / T_{1/2} = -0.309$ $0.446 = t / T_{1/2}$ t = 0.446 x 87.7 = <u>39.1 yr</u> Stockpile is 39.1 years old	1 for correct equation and substitutions 1 mark for answer ECF from part (a).	Answers in seconds acceptable. Accepted both 73.4% activity and 26.6% due to ambiguity in question.
(c)	${}^{238}_{93}Np \rightarrow {}^{238}_{94}Pu + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$	0.5 for including any two of the three products correctly. 1 mark for all three correct.	Answered well. Many variations of electron were marked as correct.
(d)	mass difference between left and right hand sides of equation Δm = 238.050946 – (238.049553 + 0.000549) = 0.000845 u In energy terms, E_K beta = 0.000845 x 931 = <u>0.786 MeV</u> ignoring energy given to the antineutrino	1 for a mass difference calculation 1 for converting to MeV	Answered well. If students have calculated mass difference between two atoms (no beta mass include) this is acceptable due to use of term 'isotopic masses'.
(e)	Neutrino is a very light particle with zero charge and high speed.	0.5 for including any two of speed, mass, charge correct 1 mark for all three correct	Very few students had all three explanations correct. Many considered it massless.
(f)	Mass defect = mass of components – mass of atom $= [\,94\,(m_p + m_e) + 144 \times m_n\,] - 238.049553$ = [94 (1.00727647 + 0.000549) + 144 x 1.008665] – 238.049553 = [94.735541 + 145.24776] – 238.049553 = 239.983301 – 238.049553 = 1.93 u Hence Binding Energy = 1800 MeV Binding Energy / nucleon = 1800 / 238 = <u>7.56 MeV /nucleon</u>	1 for finding mass of 94 protons and 144 neutrons 1 for finding difference 0.5 for converting to energy 0.5 for dividing by 238	This question was poorly answered. Very few students were able to successfully calculate the answer including electrons.

C8	Answer	Marking Guide	Marker's Comment
Question 21			
(a)	Electrons will have an energy $= qV = 1.6 \times 10^{-19} \times 60\,000$ $=$ <u>9.6×10^{-15} J</u>	1 for answer	Mostly well answered. Incorrect answers included 60000J, or multiplied by h or k_E. Some answers were also given in eV despite explicit instructions. Too many students tried to use $KE = 1/2mv^2$.
(b)	de Broglie wavelength $\lambda = h/mv$ For the electron: $½ mv^2 = 9.6 \times 10^{-15}$ $v = 1.45 \times 10^{8}$ m s^{-1} ignoring Special Relativistic effects $mv = 1.32 \times 10^{-22}$ kg m s^{-1} $\lambda = h/mv = 5.01$ <u>$\times 10^{-12}$ m</u>	1 for velocity 1 for momentum 1 for wavelength 3 for correct answer	b) and c) either solved completely or awarded few marks. It was clear many did not recognize the difference between electrons and X-rays. Many assumed e^- had velocity of c, or 60000 ms^{-1}. No marks awarded if answer for c) presented as answer for b)
(c)	Highest energy of X Rays $= 60$ keV or 9.6×10^{-15} J $= hc/\lambda$ $\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 9.6 \times 10^{-15}$ $=$ <u>2.07×10^{-11} m</u>	1 for recognising that photon energy is answer from answer from a) 1 for answer	See b) above. Some students used velocity of electron determined above instead of c.
(d)	By the acceleration of the electrons passing close to a nucleus. The extreme electric field of the nucleus creates huge accelerations leading to the creation of high energy photons. The process is known as Bremsstrahlung emission.	1 for any answer referring to interaction with nucleus or slowing down of electrons	Fewer students got this correct than (f) below. Answers such as "by constant bombardment with electrons" gained 0 marks.
(e)		1 for same cut off 1 for intensity larger everywhere -0.5 if characteristic shift	Common errors were shifting cutoff wavelength and moving/neglecting characteristic wavelengths.

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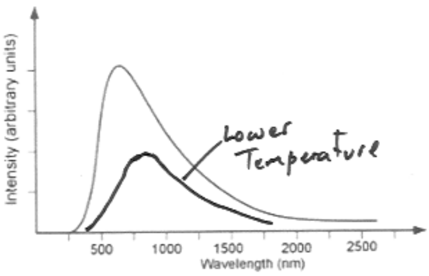
C8	Answer	Marking Guide	Marker's Comment
(f)	Because of the high energy of the cathode ray electrons, atomic electrons of the target anode metal are knocked out from all quantum levels of the atomic structure. Photons emitted as electrons fall into the quantum levels are often in the X-ray region and are of fixed wavelengths – line spectra in the X-ray region.	1 for knocking free inner electrons 1 for higher electron falling and emitting photon	This question was generally well answered. No mention of L / K shell required.
Question 22			
(a)	A black body is a perfect absorber of all electromagnetic radiation wavelengths. No reflectance occurs at any wavelength.	1 for any correct statement	There was a variety of incorrect answers supplied. This reinforces the need to take a dictionary into exams.
(b)	The solving of the black body emission curve led to the discovery of quantum mechanics.	1 for any reference to quanta	Light particle theory garnered 0 marks. Answers needed to include quantum, quantized energy, discrete packages of energy, wave/particle duality of light etc.
(c)	$\lambda_p = 2.90 \times 10^{-3} / T$ So $T = 2.90 \times 10^{-3} / 625 \times 10^{-9}$ = <u>4640 K</u>	0.5 for answer 0.5 for unit	This question was generally well answered. Main errors were orders of magnitude calculation.
(d) 		1 peak moves right 1 intensity lower at all points	Very few students received full marks Most answers included lower peak, and shifted right, but most included a right shift that crossed the existing line.

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