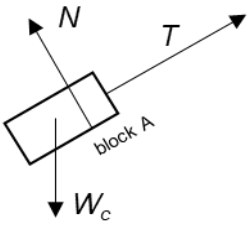
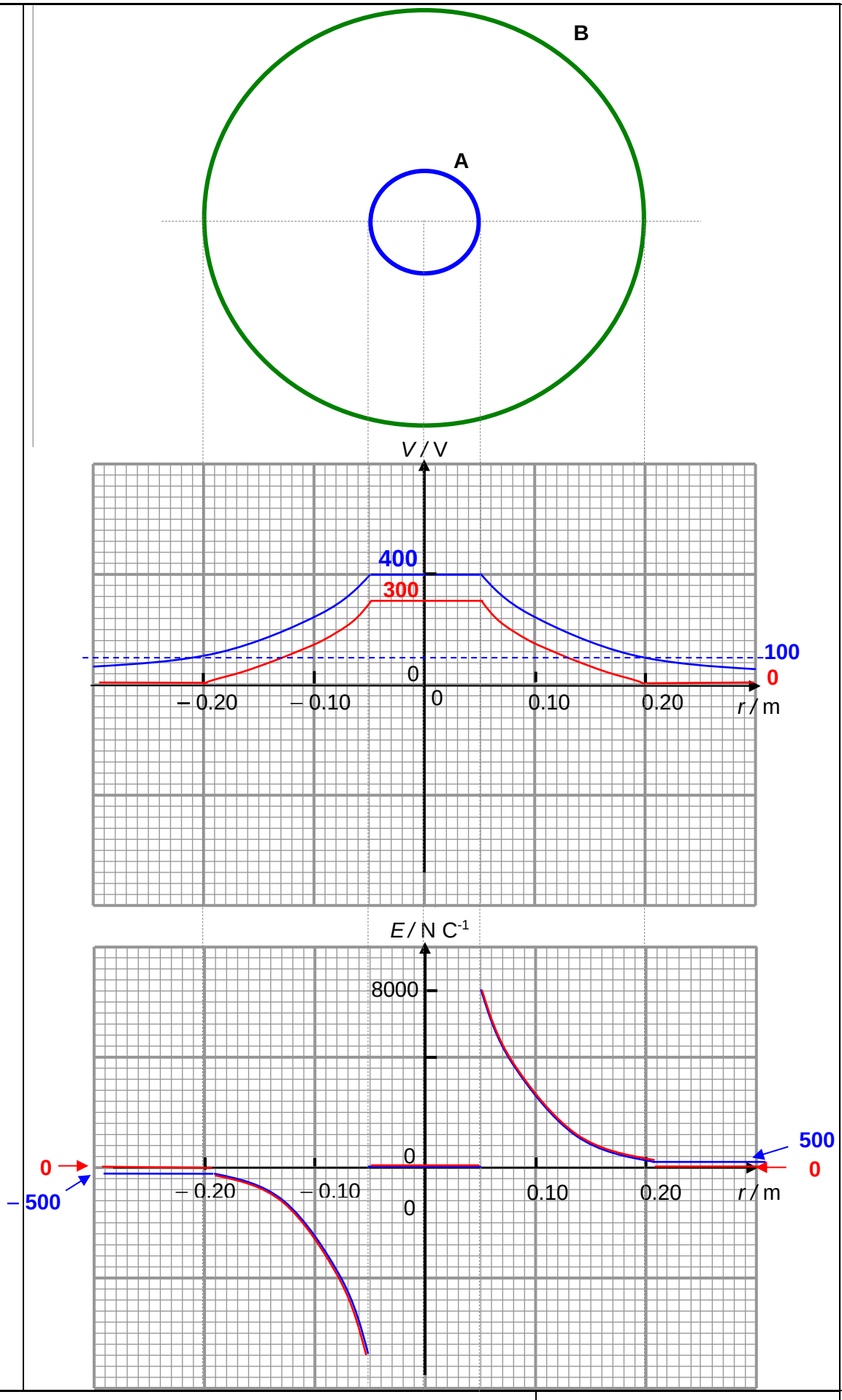
Annotations used in marking
BOD - Benefit of doubt
ECF - Error carried forward
POT - Powers of ten error
TE - Transfer error
CE - Calculation error
XP - Wrong physics
ENG - Generally bad english, phrasing and expression
PP - Poor presentation of answers

Q1	Suggested Answer	Marker's Report
(a)(i)	 Legend: N – normal contact force T – tension of string W_C – weight of block A	This part was generally well done. Some students omitted one of the forces and were unable to get full credit.
	Forces correctly labelled (ruler should be used) Correct direction indicated (T longer in length than component of W_c along slope)	
(a)(ii)	**Taking mass B as the system** $m_B g - T = m_B a$ $(8.3 \times 9.81) - 54 = 8.3a$ $a = 3.30\ \text{m s}^{-2}$	This question was answered well by students who understood the concepts.These students obtained full credit. The rest attempted to calculate based on the entire system but failed due to the lack of data. Others were confused with the resolution of the forces.
	Taking mass A as the system $T - m_A g \sin 50° = m_A a$ $54 - (m_A \times 9.81 \sin 50°) = m_A \times 3.30$	
	$m_A = 4.99\ \text{kg}$	
	$= 5.0\ \text{kg}$ (2 s.f.) (shown)	
(b)(i)	Force on block A = gradient $= \frac{-2.00 - (-10.00)}{3.00 \times 10^{-3}}$ $= 2670\ \text{N}$ (3 s.f.)	Most errors on this part are due to the wrong exponent.
	Force on block A $=$ – Force on block C $= -2670\ \text{N}$	Most students did not account for N3L in this part and hence failed to obtain full credit.

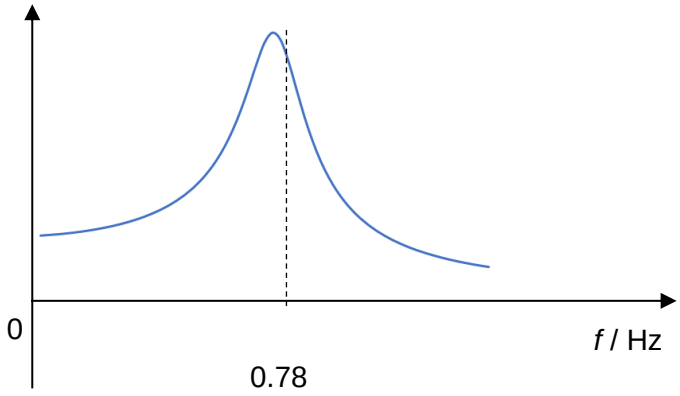
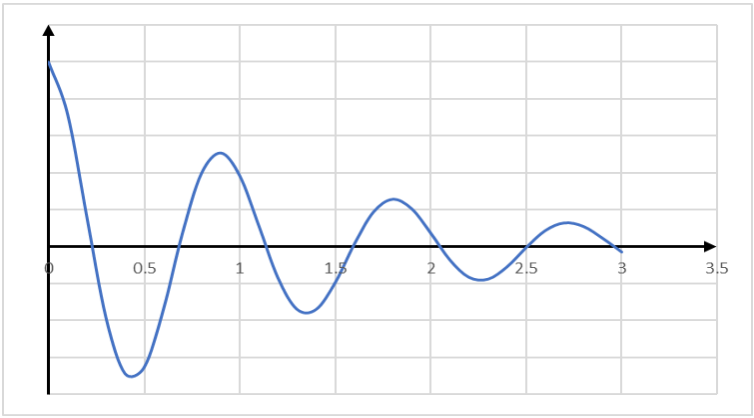
(b)(ii)	$v_A = \dfrac{p_A}{m_A}$ $= \dfrac{-2.00}{5.0}$	The vast majority of students were successful in this part.
	$= -0.40\ \text{m s}^{-1}$	A number of students forgot to express the answer in appropriate s.f.
(b)(iii)	Total momentum conserved: $p_i = p_f$ $p_i = p_{fA} + p_{fC}$ $p_{fC} = p_i - p_{fA} = -10.00 - (-2.00) = -8.00\ \text{N s}$	Students who understood the concepts performed well in this question, obtaining full credit.
	$v_C = -\dfrac{8.00}{10} = -0.80\ \text{m s}^{-1}$	Students who faltered in this question, usually were confused with the directions of the momentum. Some students who used the SUVAT approach to obtain velocity values were successful.
	Total KE before collision $= \dfrac{1}{2}m_A u^2$ $= \dfrac{1}{2}(5.0)(\dfrac{-10.00}{5.0})^2$ $= 10\ \text{J}$ Total KE after collision $= \dfrac{1}{2}[m_A v_A{}^2 + m_C v_C{}^2]$ $= \dfrac{1}{2}[(5.0)(-0.40)^2 + (10)(-0.80)^2]$ $= 3.6\ \text{J}$ **OR** relative speed of approach $= u_A - u_C$ $= 2.0\ \text{m s}^{-1}$ relative speed of separation $= v_C - v_A$ $= 0.80 - 0.40$ $= 0.40\ \text{m s}^{-1}$	Most students were familiar with the conservation of KE/relative speed approaches in determining whether the collision was elastic.
	Since total KE is not conserved, the collision is not elastic. OR Since relative speed of approach is not equal to the relative speed of separation, the collision is not elastic.	

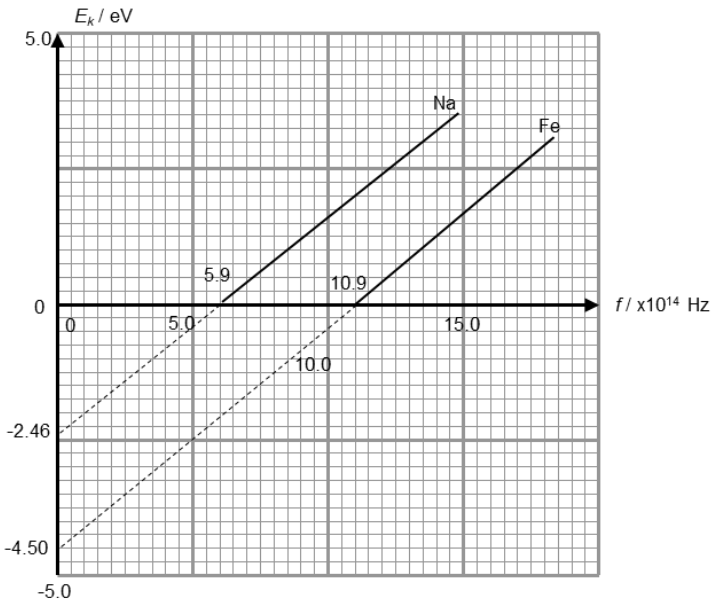
Q2		
(a)	Electric potential at a point in an electric field is defined as the work done per unit positive charge by an external agent in bringing a small test charge from infinity to that point,	Most students only obtained 1 out of 2 marks. Wrong terms used include "work done" instead of "work done per unit charge", and "stationary charge" even though the charge is being moved. Essential terms that were left out include "external agent" and "positive".
	without producing any acceleration.	This was left out by some students.
(b)	$V \propto \frac{1}{r}$ $\frac{V_2}{400} = \frac{0.050}{0.200}$ $V_2 = 100\ \text{V}$	This part was well answered.
	$E \propto \frac{1}{r^2}$ $\frac{E_2}{8000} = \left(\frac{0.050}{0.200}\right)^2$ $E_2 = 500\ \text{N C}^{-1}$	This part was well answered.
(c)(i)1	Refer to sketches	
	$-R < r < R$: Horizontal line $V_{\text{inside}} = +400$ V	This part was well answered.
	• *(r < – R) and (r > R)* : Curve $V = +$ ○ $V_{0.050\text{m}} = +400$ V $V_{0.200\text{m}} = +100$ V	This part was well answered. A few students did not sketch the graph to pass through the points at ±0.1 m and ±0.2 m. Some answers did not include range from -0.2 m to 0.2 m.
(c)(i)2	$0 < r < R$: Horizontal line $E_{\text{inside}} = 0$	This part was well answered.
	• $(-R < r < 0)$ and $(R > r > 0)$: Curve & direction ○ (When $r = +$, $E = +$) (When $r = -$, $E = -$) ○ $E_{0.050\text{m}} = \pm 8000\ \text{N C}^{-1}$ $E_{0.200\text{m}} = \pm 500\ \text{N C}^{-1}$	Wrong answers included taking the wrong direction of E as positive, not sketching the graph to pass through the points at ±0.1m and ±0.2m. Some answers did not include range from -0.2m to 0.2 m.

(c)(ii)1	• $-R < r < R$: $V_{inside} = +300$ V (horizontal line) • *(r < – R) and (r > R)* : Curve V = + *(r < – R) and (r > R)* : horizontal line at $V_{0.200m} = 0$	This was very poorly answered even for students who had full marks for **(c)(i)**. Students need to consider the graph for sphere A, and then determine the <u>scalar sum</u> of graphs for sphere A and sphere B.
(c)(ii)2	• Between $E_{0.050m}$ and $E_{0.200m}$: Curve & direction ○ (r = +, E= +) (r = –, E = –) ○ $E_{0.050m} = \pm 8000$ N C^{-1} ○ $E_{0.200m} = \pm 500$ N C^{-1} (r = +, E= +) (r = –, E = –) • $E_{inside} = 0$ $E_{beyond\ 0.200m} = 0$	This was very poorly answered even for students who had full marks for **(c)(i)** where some of the graphs drawn clearly did not apply the equations for V and E. Students need to consider the graph for sphere B, and then determine the <u>vector sum</u> of graphs for sphere A and sphere B.


B
A
V / V
400
300
100
0
0
– 0.20
– 0.10
0
0.10
0.20
r / m
E / N C-1
8000
0
0
0
– 500
500
0
– 0.20
– 0.10
0.10
0.20
r / m

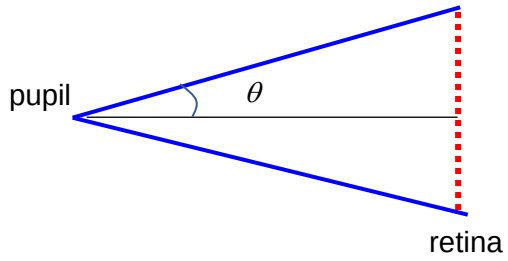
<table>
<tr><td>3</td><td></td><td></td></tr>
<tr><td rowspan="2">(a)</td><td>First Law of Thermodynamics states that the <u>increase in internal energy of a system</u></td><td>A number of students incorrectly stated “change” in their answers.</td></tr>
<tr><td>is the sum of the <u>heat supplied to</u> the system and the <u>work done on</u> the system.</td><td></td></tr>
<tr><td rowspan="4">(b)</td><td>$q_{to} = (2.26 \times 10^6)(5.0)$</td><td></td></tr>
<tr><td>$\Delta V = (\frac{5.0}{0.598} - \frac{5.0}{1000})$</td><td>Some students are still not finding change of quantities the right way.</td></tr>
<tr><td>$w_{on} = -(1.01 \times 10^5)(\frac{5.00}{0.598} - \frac{5.00}{1000})$</td><td>A number of students found work done by the system instead.</td></tr>
<tr><td>$\Delta U = q_{to} + w_{on}$
$= 1.05 \times 10^7$ J (3 s.f.)</td><td></td></tr>
<tr><td rowspan="2">(c)(i)</td><td>As the product of p and V at state C is greater than the product of p and V at state D,
<u>OR</u>
$\Delta U = q_{to} + w_{on}$
Since q_{to} is 0 and w_{on} is negative due to expansion,</td><td rowspan="2">This part was well answered.</td></tr>
<tr><td>State C is at a higher temperature.</td></tr>
<tr><td>(c)(ii)</td><td>
<table>
<tr><th>section of cycle</th><th>heat supplied to gas / J</th><th>work done on gas / J</th><th>increase in internal energy of gas / J</th></tr>
<tr><td>A to B</td><td>0</td><td>300</td><td>300</td></tr>
<tr><td>B to C</td><td>2580</td><td>- 740</td><td>1840</td></tr>
<tr><td>C to D</td><td>0</td><td>- 440</td><td>- 440</td></tr>
<tr><td>D to A</td><td>-1700</td><td>0</td><td>- 1700</td></tr>
</table>
</td><td>This part was well answered.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Q4</td><td></td><td></td></tr>
<tr><td rowspan="2">(a)(i)</td><td>Taking the direction of displacement as positive,
$F_R = mg - T$
$ma = mg - k(d + x)$</td><td>This part was very badly done. Most candidates did not show this step at all. Candidates need to be aware that show questions requires the student to clearly demonstrate their Physics concepts.</td></tr>
<tr><td>Since $kd = mg$
$ma = -kx$
$a = -\frac{k}{m}x$</td><td>Most students incorrectly started with this step which does not show their understanding of the problem.</td></tr>
</table>

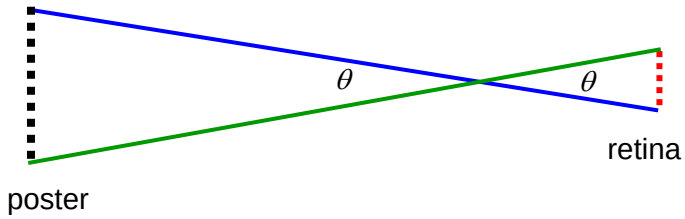
(a)(ii)	Negative sign of expression shows that acceleration acts in the opposite direction of the displacement. Since *k* and *m* are constants, acceleration is directly proportional to displacement.	A number of students did not refer to the equation and simply stated the conditions for SHM.
(a)(iii)	$a = -\frac{k}{m}x$ $\omega^2 = \frac{k}{m}$ $(2\pi f)^2 = \frac{1.2}{50\times10^{-3}}$ *f* = 0.780 Hz (3 s.f.)	This question was generally well done.
(a)(iv)	*A* / arbitrary units  Correct shape, left side must be higher than right side, not symmetrical, cannot start from origin Peak slightly to the left of 0.78 Hz	Some students misunderstood the question and drew a totally irrelevant damping curve. Some students were careless with the shape of the graph.
(b)(i)	$k_2 = 2k$ $\omega^2 = \frac{2k}{m}$ $(2\pi f)^2 = \frac{2.4}{50\times10^{-3}}$ *f* = 1.10 Hz (3 s.f.)	This part was badly done. Many students were unaware this is a series spring situation.
(b)(ii)	 Oscillating graph with period of about 0.91 s or slightly longer, must start from x_o at $t = 0$ Amplitude is decreasing exponentially with time	Many students failed to show that amplitude is decreasing exponentially with time.

Q5		
(a)(i)	It is a <u>quantum</u> of <u>electromagnetic radiation</u> energy.	This part of the question was well answered.
	The <u>energy of a photon</u> E is <u>hf</u>, where <u>h is the Planck's constant</u> and <u>f is the frequency</u> of the electromagnetic radiation.	Some students did not mention this point.
(a)(ii)	$E = h\frac{c}{\lambda}$ $= 6.63\times10^{-34} \times \frac{3.00\times10^{8}}{390\times10^{-9}}$ $= 5.10\times10^{-19}\,\text{J}$ $= \frac{5.10\times10^{-19}}{1.60\times10^{-19}}$	This part of the question was well answered. Most students were able to apply the photon energy equation.
	$= 3.188$ eV	Intermediate value should be given to at least 4 s.f.
	$= 3.19$ eV (3 s.f.) (shown)	
(a)(iii)1		This part of the question was well answered by students who understood the concepts. Main errors were due to the lines not being parallel or neglecting to include the vertical intercepts. Some students skipped the entire segment altogether.
	Parallel lines drawn	
	Correct labeling on x-axis (5.9,10.9)	
	Correct labeling on y-axis (-2.46,-4.50)	
(a)(iii)2	Gradient – no change because the gradient is the Planck's constant and not dependent on the intensity of light	This part was well answered by most of the students who attempted. The rest skipped the part.
	Vertical intercept – no change because the vertical intercept is work function is dependent on the metal and not dependent on the intensity of light	
(b)(i)	13.6 eV Electron energy level difference between lowest energy state to 0 eV.	Most students were able to state the energy level. Some wrong answers included subtraction of energy between levels.

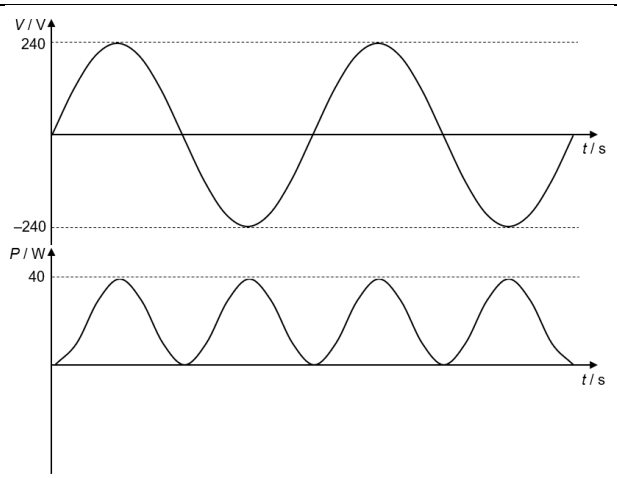
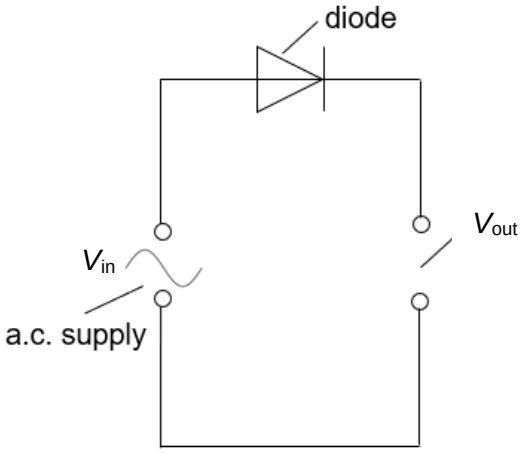
(b)(ii)	The highest energy level is 0 eV. **OR** The electrostatic force between the electron and nucleus is attractive. **OR** Positive work done by external force to ionise the hyrogen atom.	Students were generally able to state one of the correct reasons
(b)(iii)	Only photons with energy equal to the energy difference between the energy levels will be absorbed.	Most students were unable to obtain full credit for this part. Often they missed one of the main points of the answer, especially the last segment.
	The electrons in the lower energy state will absorb the photons and get excited to a higher energy level. Photons not absorbed will continue to travel to screen.	
	Excited electrons will return to lower energy level by emitting photons in all directions, resulting in dark lines at these wavelengths as the photons is much smaller in numbers compared to the other unabsorbed photons.	
Q6		
(a)(i)	A stationary wave is formed when <u>two progressive waves of the same type</u>	Most answers included "progressive".
	of <u>equal amplitude</u>, equal <u>frequency</u> (or wavelength) and <u>same speed</u>, meet when they travel in <u>opposite directions</u>.	Wrong answers were "velocity" instead of "speed", and leaving out amplitude.
(a)(ii)1	For fundamental frequency, length of string $L = \frac{\lambda}{2}$	
	Consider length of string L, and speed of each progressive wave, $v = f\lambda$ $405 = (622)\,2L$ $L = 0.326\,\text{m}\ (3\ \text{s.f.})$	Some students only calculated the length of string, but not the wavelength of progressive wave.
(a)(ii)2	$v = \omega\sqrt{x_0^2 - x^2}$ $v_{max} = \omega x_0$ $= 2\pi(622)\,3.3\times10^{-3}$ $= 12.9\,\text{m s}^{-1}\ (3\ \text{s.f.})$	This part was not well answered.
	$= 12.9\,\text{m s}^{-1}\ (3\ \text{s.f.})$	
(a)(iii)1	$I = \frac{P}{2\pi r^2}$ $= \frac{200}{2\pi(10.0)^2}$	Instead of area of a hemisphere, equations of area of sphere, and volume of sphere were given.
	$= 0.318\,\text{W m}^{-2}\ (3\ \text{s.f.})$	

(a)(ii)	**Possible reasons (any 2):** Explanation in blue (NOT part of the answers)	
	• If the 2 identical loudspeakers are far apart, the path difference between the 2 waves is significant and their amplitudes are significantly different at all points (except the mid point/middle section). As amplitude of each wave decreases with distance travelled from the source, the resultant amplitudes are non-zero at every point between the loudspeakers (hence nodes are NOT formed) except at the mid point. • Waves reflections from surfaces will superpose with the 2 waves from the loudspeakers. Nodes and antinodes are NOT formed. • There is an obstacle between the 2 loudspeakers, and the 2 waves are unable to meet. Nodes and antinodes are NOT formed. • Air in the medium is not stationary (e.g. if wind is blowing from one speaker to another, one wave has a smaller, and one has a larger frequency than the original frequency). Nodes and antinodes are NOT formed.	As the 2 loudspeakers are identical, the 2 progressive waves must have the same amplitude, speed and frequency (and phase). Some wrong answers include suggesting that the waves have different amplitudes.
	Additional Notes: • The 2 identical loudspeakers can be any distance apart except large distance (refer to 1). • If the distance between the 2 loudspeakers L is less than half a wavelength where at most only 1 node and 1 antinode are formed. As the node and antinode are $\frac{\lambda}{4}$ apart, wavelength is $4L$. • If only 1 loudspeaker is used. The loudspeaker is placed at one open end (a pressure node) to produce a progressive wave. The second progressive wave is produced as a reflected wave at the other end. The length of tube L must be ○ $L = \frac{(2n+1)\lambda}{2}$ *where* $n = 0, 1, 2, \ldots$ (for a closed end), or ○ $L = \frac{n\lambda}{2}$ *where* $n = 0, 1, 2, 3, \ldots$ an open end).	

(b)(i)		Answers with wrong physics included using the double slit formula.
	For single slit diffraction, at the 1st minima m = 1, $\sin\theta = \frac{m\lambda}{b}$ ..... (1)	Answers with wrong physics included using the diffraction grating equation formula.
	For small angle approximation, $\sin\theta \approx \tan\theta$ ..... (2)	
	$\tan\theta = \sin\theta$ $\tan\theta = \frac{\lambda}{b}$ $\frac{w/2}{L} = \frac{\lambda}{b}$ $\frac{4.80\times10^{-6}/2}{17.0\times10^{-3}} = \frac{\lambda}{3.0\times10^{-3}}$	
	$\lambda = 4.24\times10^{-7}\,\text{m}$ $= 424\,\text{nm}$ (3 s.f.)	
	OR Pythagoras Theorem can be used to derive equation for θ.	
(b)(ii)1	Two images are just resolved	The term must be include "just" as this is the minimum condition for the 2 images to be distinguishable. Wrong terms used were "differentiate" and "distinguish" instead of "resolved".
	when the central maximum of one image falls on the first minimum of the other image.	
	Additional Notes: If distance between the eye and poster is decreased, angular separation will increase, and the diffration patterns will be further apart and appear as 2 images. As the 2 images are resolved, the 2 objects are distinguishable.	

(b)(ii)2		
	Applying Rayleigh Criterion, for <u>minimum</u> wavelength $\theta_R = \frac{\lambda_{min}}{b}$ …… (1) $= \frac{380\times10^{-9}}{3.00\times10^{-3}}$ $= 1.27\times10^{-4}$ rad (3 s.f.)	
(b)(ii)3	By geometry and small angle approximation, for minimum distance between 2 adjacent pixels, $\theta_{min} = \frac{d_{min}}{D}$ …… (2)	Most correct answers provided calculations for both the vertical and horizontal distances between adjacent pixels. Students only need to identify the minimum angle is due to the smaller distance and smallest wavelength of blue.
	$d_{min} = \frac{72\times10^{-2}\text{ m}}{710}$	
	$\theta_{min} = \frac{d_{min}}{D}$ $= \frac{\left(\frac{72\times10^{-2}}{710}\right)}{1.5}$ $= 6.761\times10^{-4}$ rad	
	Since $\theta_{min} > 2.91\times10^{-4}$ rad, the observer can distinguish between any two adjacent blue pixels of the smaller distance and smallest wavelength of blue.	
(b)(ii)4	Slit width increases, angular resolution decreases, hence minimum distance increases.	

Q7		
(a)(i)	$B_C = 7.5 \times 10^{-3}$ T	This part was well answered.
(a)(ii)	$B = \frac{\mu_0 NI}{2r}$ $7.5\times10^{-3} = \frac{\mu_0(300)(2.0)}{2(0.050)}$	This part was well answered.
	$\mu_0 = 1.25 \times 10^{-6}$ H m^{-1}	
(b)(i)	The <u>magnitude of the induced e.m.f.</u> in a conductor is <u>directly proportional</u> to the <u>rate of change of magnetic flux linkage</u> experienced by the conductor.	Many students got this definition wrong. Students need to put in more effort to remember the key definitions.
(b)(ii)	0.024 – 0.036 m	This part was well answered.
(b)(iii)	The gradient of the graph is the maximum.	A number of students did not base their answer from the graph and simple applied Faraday's law with no reference to the question.
	As coil Q is moved at a steady speed, the rate of change of magnetic flux linkage is the greatest. Hence induced e.m.f. is maximum.	
(b)(iv)	When coil Q is moved to the right, the magnetic flux will decrease.	Similarly, this part was not answerd well as many students simply applied Lenz law without clear explanation of the decrease in magnetic flux and description of the effect that is induced to oppose this decrease.
	By Lenz's law, an induced current caused by an induced e.m.f. in coil Q will flow in the same direction as the current in coil P to create a magnetic field to the left.	
(b)(v)1	B at 0.040 m = 3.6×10^{-3} T $\Delta B = 3.6\times10^{-3} - 7.5\times10^{-3}$ $= -3.9\times10^{-3}$ T	Many students did not include the negative sign in their answers. A negative change should be indicated unless the question specified for magnitude.
(b)(v)2	$\varepsilon_{ave} = -\frac{d\phi}{dt}$ $= -\frac{dNBA\cos\theta}{dt}$ $= -NA\frac{dB}{dt}$	This part was well answered.
	$= -\frac{(5000)(1.5\times10^{-4})(-3.9\times10^{-3})}{0.25}$	
	= 1.17×10^{-2} V	

(c)(i)	Value of an alternating current that is equal to <u>the steady direct current</u> that would <u>dissipate heat at the same average rate in a given resistor</u>.	Many students got this definition wrong. Students need to put in more effort to remember the key definitions.
(c)(ii)1		This part was well answered. Some incorrect graphs include sinusoidal and modulus functions.
	$P_0 = 2P_{ave}$ $= 2(20)$ $= 40$ W	
	Correct shape for 2 complete cycles	
(c)(ii)2	$\frac{V_{0\,S}}{V_{0\,P}} = \frac{N_S}{N_P}$ $\frac{V_{0\,S}}{240} = \frac{1}{50}$ $V_{0\,S} = 4.8$ V	This part was well answered.
	$V_{r.m.s.\,S} = \frac{4.8}{\sqrt{2}}$ $= 3.39$ V (3 s.f.)	
(c)(iii)		This part was not well answered. Circuit drawings did not follow what the question specified. Common mistakes include: • wrong diode symbol • use of battery or d.c. source • no indication of V_{in} and V_{out}
	Labelled circuit diagram with correct symbols showing V_{in}, V_{out}, a.c. supply and diode.	
(c)(iv)	$V_{r.m.s.\ half\text{-}wave} = \frac{4.8}{2}$ $= 2.4$ V	Many students did not know how to find the $V_{r.m.s.}$ for a half-wave rectified source.