**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

| Qn | Suggested Answer | Marker's Report |
|---|---|---|
| **Q1** | | |
| **(a)(i)** | The absolute uncertainty of both measurements is the same.<br>OR<br>Fractional/percentage uncertainty is reduced by measuring *N* coins. | Some students were unable to show understanding that the absolute uncertainty for both ways of measures is the same. |
| | By measuring *N* coins, the absolute uncertainty of the thickness of 1 coin is divided by *N*.<br>OR<br>By measuring *N* coins, fractional uncertainty is $\Delta x$ / *T*.<br>By measuring 1 coin, fractional uncertainty is $\Delta x$ / *T*/*N*. | |
| **(a)(ii)** | Use a micrometer screw gauge/vernier caliper as the instrument has smaller absolute uncertainty compared to the half metre rule. | This part was well done. |
| **(b)** | $pV = nRT$<br>$p = \dfrac{0.00200 \times 8.31 \times (273.15 + 36.7)}{\frac{4}{3}\pi(0.0250)^3}$<br>$= 78682$ Pa | Most students were able to do this step correctly with a handful of students forgetting to convert temperature to K. |
| | $\pm\dfrac{\Delta p}{p} = \pm(3\dfrac{\Delta d}{d} + \dfrac{\Delta T}{T})$<br>$= \pm[3(\dfrac{0.1}{50.0}) + \dfrac{0.1}{(273.15 + 36.7)}]$ | A number of students did not convert temperature to K when calculating uncertainty. |
| | $\pm\Delta p = \pm 497$ Pa<br>$p \pm \Delta p = (78700 \pm 500)$ Pa | Some students did not express the absolute uncertainty to 1 s.f. |
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| **Q2** | | |
| **(a)(i)** | <u>Constant velocity</u> in the <u>horizontal</u> direction and a <u>constant acceleration</u> in the <u>vertical</u> direction | Some students did not mention about the motion in the horizontal direction. |
| **(a)(ii)** | $v^2 = u^2 + 2as$ | |
| | $0 = (20.0 \sin\theta)^2 + 2(-9.81)(15.8)$ | |
| | $\theta = 61.7°$ | Intermediate value should be given to at least 3 s.f. |
| | $\theta = 62°$ (0 d.p.) (shown) | |

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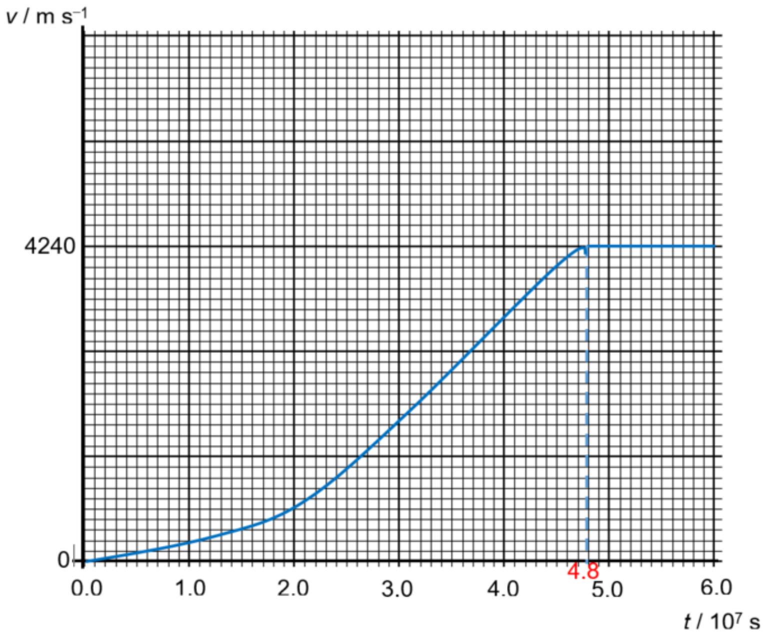
| **(a)(iii)** | $v_y = u_y + a_y t$<br>$0 = 20.0 \sin 61.7° - 9.81t$<br>$t$ = 1.80 s (3 s.f.) | Students did not take into account direction of acceleration and hence did not use negative sign for $a_y$. |
| **(b)(i)** | Since force exerted on the spaceship $F$ is constant but mass of the spaceship decreases with time, given that $F = ma$, $a$ increases with time. | Some students did not indicate that force exerted on spaceship is constant. |
| **(b)(ii)** | $F_{\text{on fuel}} = v_{rel} \dfrac{dm}{dt}$<br>$= (3.0 \times 10^4)(1.7 \times 10^{-6})$ | |
| | = 0.051 N<br>$\lvert F_{\text{on spaceship}} \rvert = \lvert F_{\text{on fuel}} \rvert$ | Students should be aware to show application of N3L. |
| **(b)(iii)** | Change in velocity = area under graph<br>$= ½(9.450 + 8.200)\times10^{-5} \times 4.80\times10^{7}$<br>$= 4240$ m s$^{-1}$<br>Final velocity = 4240 – 0 = 4240 m s$^{-1}$ | A number of students failed to realise the $x$-axis did not start from 0. |
| **(b)(iv)** |  | |
| | Increasing gradient from $t$ = 0 to $t = 4.8 \times 10^7$ s, starting from $v$ = 0 to final $v$ at 4240 m s$^{-1}$.<br>Between $t = 4.8 \times 10^7$ to $t = 6.0 \times 10^7$ s, there is no more force. Therefore, constant $v$ at 4240 m s$^{-1}$. | Some students did not indicate value of max $v$ in graph nor time where constant $v$ is attained. |
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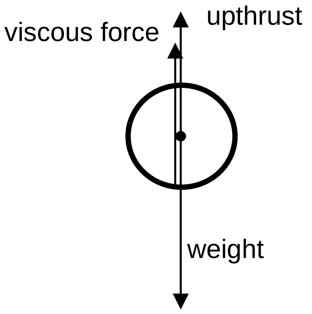
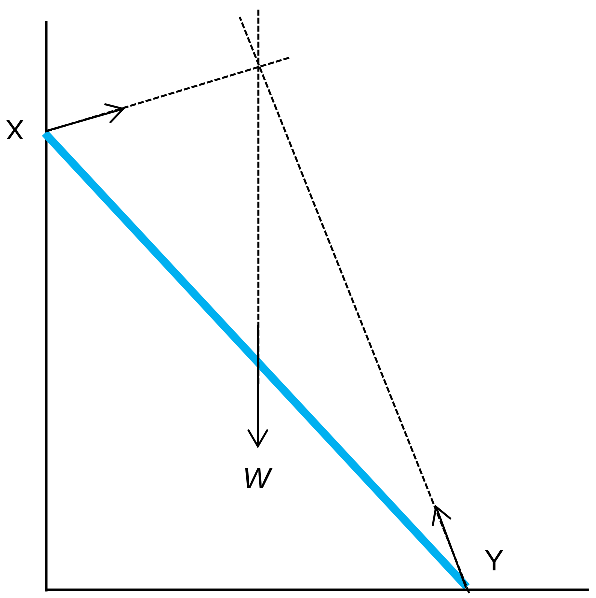
<table>
<tr><td>Q3</td><td></td><td></td></tr>
<tr><td rowspan="3">(a)</td><td><br>Correct labelling of forces</td><td>The free body diagram was not well drawn. Many students missed out drawing viscous force or upthrust in the diagram.</td></tr>
<tr><td>As <u>speed</u> of metal ball <u>increases</u>, <u>viscous force increases</u>. As viscous force increases, <u>net acceleration decreases</u>.</td><td>One common misconception was that upthrust increases as the metal ball falls.</td></tr>
<tr><td>When the <u>total upward force</u> (viscous force and upthrust) becomes <u>equal in magnitude</u> to the <u>weight</u> of the ball, there is <u>no net force</u>, and the metal ball reaches terminal velocity.</td><td>Some did not indicate that the upward force comprise viscous and upthrust.</td></tr>
<tr><td rowspan="2">(b)(i)</td><td>Taking moments about B,<br>$P \times 6.0\cos 30° = 150 \times 3.0 \sin 30°$<br>$P = 43.301$ N</td><td>Intermediate value should be given to at least 3 s.f.</td></tr>
<tr><td>= 43 N (2 s.f.) shown</td><td></td></tr>
<tr><td rowspan="2">(b)(ii)</td><td>The <u>horizontal component of Q</u> which is pointing to the <u>left</u> will balance <u>force P</u> which is pointing to the <u>right</u>.</td><td rowspan="2">Generally well done with some answers missing out directions such as left, right, up and down.</td></tr>
<tr><td>The <u>vertical component of Q</u> which is acting <u>upwards</u> will balance <u>W</u> which is acting <u>downwards</u>. This will allow the ladder to be in equilibrium.</td></tr>
<tr><td>(b)(iii)</td><td>Horizontal component = 43 N<br>Vertical component = 150 N<br>Magnitude of $Q = \sqrt{43^2 + 150^2} = 156$ N (3 s.f.)</td><td>This part was well done.</td></tr>
<tr><td>(b)(iv)</td><td><br>Three forces intersect at same point and force at X is facing upwards diagonally.</td><td>Some students did not check that the 3 forces drawn intersect at the same point.</td></tr>
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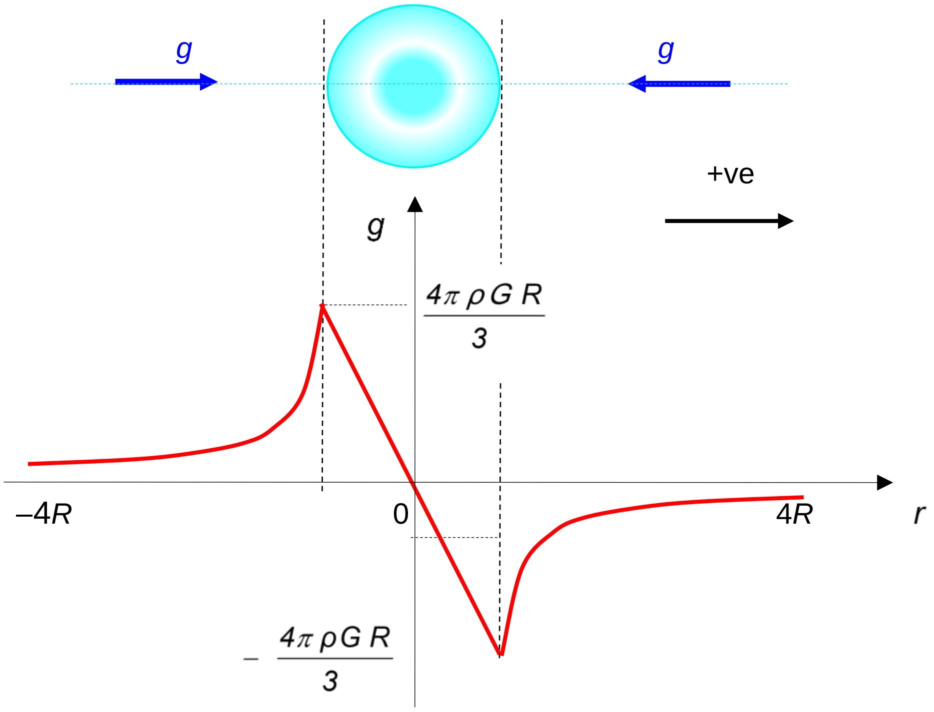
| **4** | | |
| **(a)** | $g = \frac{F}{m}$ where $F = \frac{GMm}{r^2}$<br>$= \frac{GM}{r^2}$ | Some students still did not follow the requirement of the question. |
| | as $\rho = \frac{M}{\frac{4}{3}\pi R^3}$ | |
| | $g = \frac{4\pi\rho G R^3}{3r^2}$ | |
| **(b)** |  | |
| | $-R < r < R$: straight line passing through the origin | |
| | $r < -R$ and $r > R$: inverse square graph | |
| | +ve and -ve direction of $g$ (according to stated sign convention) | Many students did not account for the sign convention of the gravitational field strength. |
| | $r = R$: $g = \frac{4\pi\rho G R}{3}$ | |

<table>
<tr><td rowspan="3">(c)(i)</td><td>Additional Notes: (NOT part of answer)<br>• Straight line passing through the origin indicates that the gravitational force on parcel is directly proportional to the distance from the centre of Earth.<br>• Negative gradient indicates that the gravitational force is always directed towards the centre of the Earth.<br>• Hence, net force for SHM is provided by gravitational force.</td><td></td></tr>
<tr><td>By N2L, $ma = mg$<br>$a = \frac{4\pi \rho G}{3} r \quad \cdots\cdots(1)$<br>For SHM, $a = \omega^2 x \quad \cdots\cdots(2)$<br>Comparing $\omega^2 = \frac{4\pi \rho G}{3}$</td><td>Wrong physics include equating g to centripetal acceleration (circular motion) instead a to and fro acceleration (SHM).</td></tr>
<tr><td>$\left(\frac{2\pi}{T}\right)^2 = \frac{4\pi \rho G}{3}$<br>$T = \sqrt{\frac{3\pi}{\rho G}}$</td><td>A number of correct expressions even though it was not simplified.</td></tr>
<tr><td rowspan="2">(c)(ii)</td><td>Maximum time taken (as assuming released from rest in Singapore) = half a period</td><td>Many correctly deduced the time to be half a period.</td></tr>
<tr><td>$\frac{T}{2} = \frac{1}{2}\sqrt{\frac{3\pi}{\rho G}}$<br>$= \frac{1}{2}\sqrt{\frac{3\pi}{(5.51\times 10^3)6.67\times 10^{-11}}}$<br>$= 2530 \text{ s (3 s.f.)}$</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td></tr>
<tr><td rowspan="3">(a)(i)</td><td>As the <u>light intensity increases</u>, the <u>resistance of the LDR decreases</u>.</td><td rowspan="3">This was generally well done. Some students did ignored the fact that the emf is constant and thought the voltmeter would change for Fig. 5.1(a). Students could provide a more detailed explanation on why the potential difference for the voltmeter would vary using physics concepts instead of merely stating it.</td></tr>
<tr><td>In Fig. 5.1(a), since the components are in <u>parallel</u>, as the resistance of the LDR varies, the <u>voltmeter reading will remain constant</u>.</td></tr>
<tr><td>In Fig. 5.1(b), the <u>voltmeter is placed across the fixed resistor</u> so as the <u>light intensity increases by potential divider principle</u> $V = \frac{500}{500 + R_{LDR}} \times 6.0$, the <u>voltmeter reading increases</u>.</td></tr>
<tr><td rowspan="2">(a)(ii)</td><td>By the potential divider principle,<br>$V = \frac{500}{500 + R_{LDR}} \times 6.0 = 3.75$</td><td rowspan="2">Well done if students recognized the voltmeter was placed across the 500Ω resistor. Some used a long method.</td></tr>
<tr><td>$R_{LDR} = 300\ \Omega$</td></tr>
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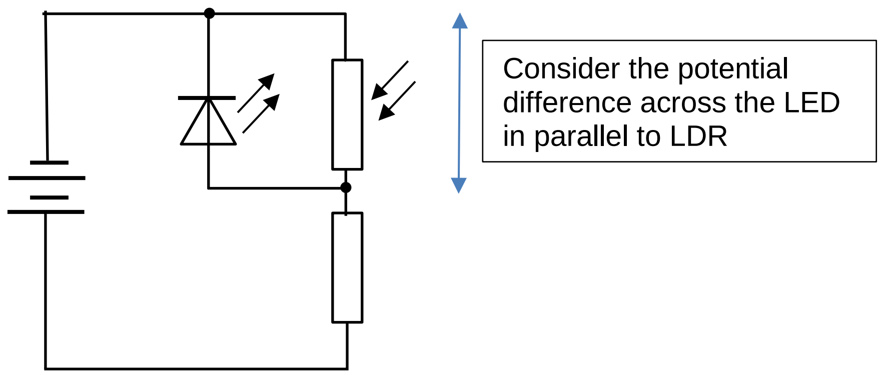
| **(b)(i)** | When dark, resistance of LDR increases, p.d. across LDR and LED increase. So the LED turns on. Resistance of LDR decreases.<br>OR<br>When bright, resistance of LDR decreases, p.d. across LDR and LED decrease. So the LED turns off. Resistance of LDR increases. | This was moderately done. The explanation should recognize the variation in the resistance of the LDR resulting in the fluctuation in potential difference across it leading to an effect on the LED. Students need to explain why there is a cycle to the process. Those who explained using current did not recognise that the potential difference across also varies so that is not an adequate explanation. When bright, it must imply the power of the LED is higher. |
| | The p.d. across LED and LDR decrease, forcing the LED to switch off.<br>OR<br>The p.d. across LED and LDR increase, forcing the LED to switch on. | |
| | When the LED is off, the p.d. across LED and LDR will increase, forcing the LED to switch on.<br>OR<br>When the LED is on, the p.d. across LED and LDR will decrease, forcing the LED to switch off. | |
| |  | |
| **(b)(ii)** | A sensible suggestion, e.g. point the LED away from the LDR / increase distance (between LED and LDR) / insert a card between (LED and LDR) | This part was not well done as it requires some thought. |
| **(c)(i)** | Horizontal line at 6.0 V. | This part was not well done as it shows if students understood how the circuit works. |
| **(c)(ii)** | When $R$ = 5.0 Ω, $V$ = 4.0 V.<br>$V = E - Ir$<br>$r = \dfrac{E-V}{I} = \dfrac{6.0-4.0}{(4.0/5.0)}$ | Students who were able to interpret the graph correctly were able to answer this. |
| | $r$ = 2.5 Ω | |
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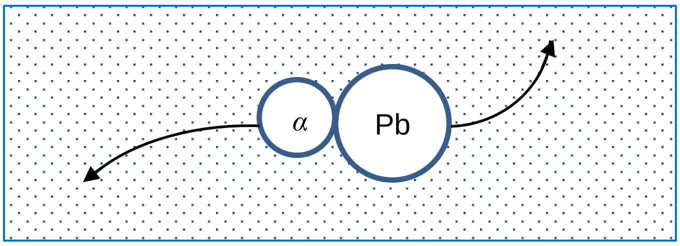
| **6** | | |
| **(a)** | The half-life of a radioactive nuclide is the mean time taken for a quantity *x* to reduce to half its initial value where *x* represents either the number, activity or count rate of radioactive nuclei. | Many students missed out the word "mean". |
| **(b)** | Spontaneous:<br>Not affected by chemical reactions and physical conditions such as temperature and pressure. | This part was badly done, students were unaware of the definition for spontaneous and random. |
| | Random:<br>No way to predict which particular nucleus in a radioactive sample will decay next. Each nucleus in a sample has the same chance of decaying per unit time. | |
| **(c)(i)** | ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e +$ energy | This part was well done. |
| **(c)(ii)** | $\lambda = \dfrac{\ln 2}{5730 \times 365 \times 24 \times 60 \times 60}$ | This part was well done. |
| | $= 3.84 \times 10^{-12}$ s$^{-1}$ (3 s.f.) | |
| **(c)(iii)** | $A = A_0 e^{-\lambda t}$<br>$5.4 = (0.23 \times 10000) e^{-3.84 \times 10^{-12} t}$ | Many students missed out the differences in mass of the two samples. |
| | $t = 1.577 \times 10^{12}$ s | |
| | $t = \dfrac{1.577 \times 10^{12}}{365 \times 24 \times 60 \times 60}$<br>= 50000 years (3 s.f.) | Some students did not explicitly show the conversion. |
| **(d)(i)** | $m_{Pb} u_{Pb} + m_\alpha u_\alpha = m_{Pb} v_{Pb} + m_\alpha v_\alpha$<br>$0 = 206 v_{Pb} + 4 v_\alpha$ | The part was generally well done. |
| | $\text{KE} = \dfrac{p^2}{2m}$<br>$\dfrac{\text{KE of Pb}}{\text{KE of } \alpha} = \dfrac{\dfrac{{p_{Pb}}^2}{2m_{Pb}}}{\dfrac{{p_\alpha}^2}{2m_\alpha}} = \dfrac{m_\alpha}{m_{Pb}} = \dfrac{4}{206}$ | |
| | = 0.019417 | |
| | = 0.0194 (3 s.f.) (shown) | |
| **(d)(ii)** | <br>Magnetic force provides centripetal force<br>$Bqv = \dfrac{mv^2}{r}$<br>$r = \dfrac{mv}{Bq}$ | This part was very badly done. Most students were unaware of how the analysis required to solve the question. |

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| | • both nuclei have the same momentum<br>• Pb nucleus has much larger charge than $\alpha$-particle<br>• Pb nucleus has smaller radius than $\alpha$-particle<br>• apply Fleming's left hand rule to determine direction of motion | |
| | Opposite direction for Pb nucleus (right) and $\alpha$-particle (left) | |
| | Correct path for Pb nucleus and $\alpha$-particle with smaller radius for Pb nucleus | |
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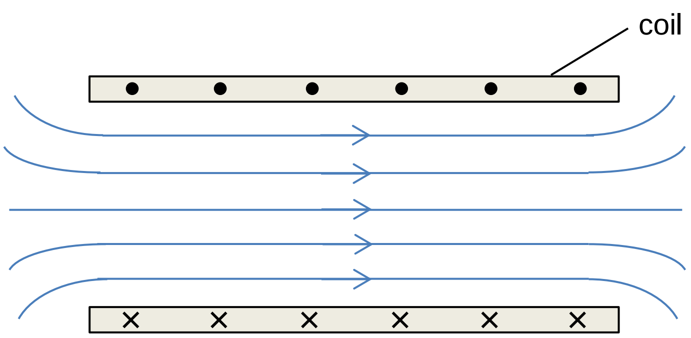
| **7** | | |
| **(a)(i)** |  | |
| | Correct direction of magnetic field with at least 5 lines | This part was not well done. Students must take more care for such sketching questions.<br><br>Common mistakes include:<br>• wrong direction of field<br>• insufficient number of lines<br>• lines that were not straight<br>• not drawing lines outside the coil<br>• irregular spacing between the lines |
| | Correct shape with equal distance between lines inside the coil<br>Lines must be straight inside the coil<br>Lines must curve outside the coil | |
| **(a)(ii)** | To reduce resistance of the coil to allow for higher current to be used in coil<br>OR<br>With high current, resistance of the coil increases, cooling will prevent overheating. | This was not well answered. Many answers were superficial and did not link to physics concepts. |
| **(b)** | Scanner generates a very strong magnetic field causes a strong magnetic force to attract metallic implants. This may harm patients with these implants by dislodging the metallic parts. | Some students gave general answers which did not explain how patients would be harmed. |
| **(c)(i)** | The hydrogen nuclei has one unpaired proton. | This part was well answered. |
| | Hence its net spin is 1/2. | |
| **(c)(ii)** | The carbon nuclei has 3 pairs of protons and 3 pairs of neutrons. Hence, it has no net spin. | This part was well answered. |
| | It is unable to absorb photons of a particular frequency. | |

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| **(d)** | Energy of photon $= hf$<br>$= h\nu$<br>$= h\gamma B$<br>$= (6.63\times10^{-34})(42.58\times10^{6})(1.5)$<br>$= 4.235\times10^{-26}$ J | |
| | $= \dfrac{4.235\times10^{-26}}{1.60\times10^{-19}}$ eV | Many students did not show the working to convert J to eV. Non trivial conversions should be shown as working. |
| | $= 2.65\times10^{-7}$ eV (3 s.f.) | |
| **(e)(i)** | Damage or destroy living cells<br>OR<br>Break bonds that hold water molecules together, forming toxic substances<br>OR<br>Creating free radicals | This part was well answered. |
| **(e)(ii)** | Energy of X-ray photon $= \dfrac{hc}{\lambda}$<br>$= \dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{10^{-10}}$ | A number of students got the range of wavelength and frequency of X-rays wrong. |
| | $= 1.99\times10^{-15}$ J (3 s.f.)<br>Since energy of X-ray photon > $6.0 \times 10^{-19}$ J, X-rays are ionizing. | |
| **(f)(i)** | Phosphorus does not have an isotope. | This part was well answered. |
| **(f)(ii)** | The hydrogen ${}^{1}_{1}H$ nuclei has a higher natural abundance of 0.99985 and is the most common hydrogen isotope. | A number of students did not comment about the natural abundance. |
| | It is also has the highest biological abundance of 0.63, which makes it the most common element in the human body. | This part was well answered. |
| **(f)(iii)** | Soft tissues are mostly made up of water and hydrogen nuclei are naturally found in water.<br>When an external magnetic field is applied, the hydrogen nuclei can absorb photons of a particular frequency.<br>As the nuclei return to their resting alignment, energy is emitted and converted to images of the soft tissues. | This part was not attempted well. Students have to have a good understanding of how MRI works but picking out key information from the passage and piecing them together. To do this, sufficient time needs to be set aside for the data analysis question (preferably 30 mins). It is evident many students did not have enough time to attempt this question. |