Paper 3 Mark scheme

Question number	Acceptable answers	Additional guidance	Mark
1(a)	An explanation that makes reference to the following points: • Comment on the data **(1)** • Correct consequent conclusion **(1)**	4.43 is an anomalous value So the mean value is too low Accept data is concordant so mean value is correct	**2**
1(b)	An explanation that makes reference to the following points: • Light gates can record short times accurately **(1)** **OR** with smaller uncertainty **(1)** • Because human reaction time is not involved **(1)**		**2**

(Total for Question 1 = 4 marks)

Question number	Acceptable answers	Additional guidance	Mark
2	• Sensible estimate of uncertainties from readings given **(1)** • Adds percentage uncertainties **(1)** • Hence calculates uncertainty in speed **(1)** • Candidate's conclusion must be supported by their estimate of the uncertainties **(1)**	Example of calculation: %U in L is (0.1/25.6) x 100 % = 0.4 % %U in F is (1/320) x 100 % = 0.3 % %U in speed is 0.7 % 328 x 0.007 = 2 Speed = 328 ± 2 All three results are within the calculated uncertainty so concludes student B is correct	**4**

(Total for Question 2 = 4 marks)

Question number	Acceptable answers	Additional guidance	Mark
3 (a)(i)	A description that makes reference to the following points: Circuit diagram showing: • Cell, variable resistor and ammeter in series and voltmeter in parallel with cell **(1)** • Recording pairs of readings of terminal p.d. and current **(1)** • Use the variable resistor to obtain 5 other pairs of readings **(1)**	Should be between 5 and 10 other pairs	**3**
3 (a)(ii)	A description that makes reference to the following points: • Plot a graph of terminal potential difference on the y-axis and current on the x-axis **(1)** • Intercept on the y-axis equals e.m.f. **(1)** • And gradient = -r **(1)**		**3**
3(b)	• From graph: after 500 charging cycles internal resistance of cell is 327 mΩ **(1)** • Use of $V = \varepsilon - Ir$ **(1)** • Use of $\frac{V_{500}}{V_0} \times 100\%$ $\frac{V_{500}}{V_0} \times 100\% = 99.6\%$ **(1)** • So manufacturer's claim is correct **(1)**	Example of calculation: $V_0 = 3.6\,\text{V} - 0.800\ \text{A} \times 0.310\ \Omega$ $= 3.6\,\text{V} - 0.248\ \text{V} = 3.352\ \text{V}$ $V_{500} = 3.6\,\text{V} - 0.800\ \text{A} \times 0.327\ \Omega$ $= 3.6\ \text{V} - 0.262\ \text{V} = 3.338\ \text{V}$ $\frac{V_{500}}{V_0} \times 100\% = \frac{3.338\,\text{V}}{3.352\,\text{V}} \times 100\% = 99.6\%$ This last mark is awarded only if the conclusion is correctly supported by the calculation.	**4**

(Total for Question 3 = 10 marks)

Question number	Acceptable answers	Additional guidance	Mark
4 (a)	Any three from: • Inconsistent precision for extension **(1)** • Lack of precision on mass, should be shown to 3 DP **(1)** • No evidence of repeat readings **(1) OR** there should be more readings to compensate for repeat readings being inappropriate **(1)** • Inconsistent intervals between readings **(1)**	Uncertainty suggested by 1 sf is far greater than that expected in practice	**3**
4 (b)	A description that makes reference to two of the following points: • use of ficidual mark **(1)** • eye close to liquorice lace to avoid parallax errors **(1)** • Fixed metre rule close to lace **(1)** • Use of set square to ensure rule vertical **(1)**		**2**

(Total for Question 4 = 5 marks)

Question number	Acceptable answers	Additional guidance	Mark
5	• Diameter is only half a division on the scale **(1) OR** diameter is measured to only 1 sf **(1)** • Hence there is a large percentage uncertainty in measurement of diameter of oil drop **(1)** • Since the volume of the drop is calculated by taking $(\text{diameter})^3$, the percentage uncertainty in volume becomes very large (3 × % uncertainty in diameter) **(1)** • Suggestion for improvement: use a larger oil drop, use a (vernier) scale capable of reading to nearest 0.1 mm, project image of droplet to larger size **(1)** • Drop will not spread out as an exactly circular area, so diameter reading may be inaccurate **(1)** • Suggestion for improvement: the diameter of spread-out oil drop should be taken a number of times across a number of different directions and a mean calculated **(1)**	Allow for identification of any other valid problems and improvements based on good physics, for example place metre rule across tray so that it is close to the surface.	**6**

(Total for Question 5 = 6 marks)

Question number	Acceptable answers	Additional guidance	Mark
6 (a)	An explanation that makes reference to the following points: • The current produces a magnetic field around the aluminium ring **(1)** • The direction of the ring field opposes the change producing it **(1)** • The fields repel, producing a force **(1)** • The electromagnetic force is equal and opposite to the weight of the ring so it remains in position shown **(1)**		**4**
6 (b)(i)	• Use of $\frac{1}{2}mv^2 = mgh$ **(1)** • $v = 2.43 \text{ m s}^{-1}$ **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2\times9.81\times0.30} = 2.43 \text{ m s}^{-1}$	**2**
6 (b)(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

(Total for Question 6 = 12 marks)

Question number	Acceptable answers	Additional guidance	Mark
7 (a)(i)	A description that makes reference to the following points: • Record nT (where n is at least 5) **(1)** • Divide measurement by n **(1)**		**2**
7 (a)(ii)	• Anomalies can be spotted **(1)** • Reduce the effect of random error **(1)**		**2**
7 (b)(i)	• BFL is smooth and thin with a definite minimum and minimum is in range 0.26 m – 0.28 m **(1)**		**1**
7 (b)(ii)	• Values read correctly from candidate's line **(1)** • h to 3 sig fig **and** T to 4 sf **(1)**	Values from their curve to within 1 small square with no unit penalty.	**2**
7 (c)	A description that makes reference to the following points: • Plot T^2h against h^2 **(1)** • C is intercept on T^2h axis **(1)** **OR** C is the value of T^2h when h^2 is zero **(1)** • Unit is m s^2 **(1)**		**3**

(Total for Question 7 = 10 marks)

Question number	Acceptable answers	Additional guidance	Mark
8 (a)	An explanation that the student's conclusion is incorrect because: • The popper returns to its original shape, even though there is a time delay **(1)** • Elastic material returns to its original shape when the deforming force is removed **(1)** • But a plastic material would suffer a permanent deformation **(1)**		**3**
8 (b)	A description that makes reference to the following points: • Refer to $v^2 = u^2 + 2as$ **(1)** • Where s is height reached, v is zero, $a = -g$ **(1)** • So $u = \sqrt{2gs}$ **(1)**	Allow argument ½ $mv^2 = mgh$ to get the same results.	**3**
8 (b)(ii)	• Air resistance will act on the popper… **(1)** • …As a decelerating force **(1)** **OR**… dissipating energy **(1)** • So the initial speed will be lower than in the absence of air resistance, so the suggestion is not correct **(1)**		**3**

(Total for Question 8 = 9 marks)

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>9 (a)</td><td>• Uses weight of displaced air = ρVg (1)
• Finds resultant force = upthrust – weight (1)
• Uses F = ma to find acceleration (1)
• Acceleration = 0.161 m s^{-2} (1)</td><td>Example of calculation:
Weight of air displaced = ρVg = 1.20 kg m^{-3}×2880 m^3× 9.81m s^{-2} = 33 903N
Resultant upward force = 33 903 N – (3400 kg × 9.81m s^{-2}) = 549 N
Acceleration = 549 N/3400 kg = 0.161 m s^{-2}</td><td>4</td></tr>
<tr><td>9 (b)*</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table></td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

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<tr><td>9 (b)*
(continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
9 (b)* (continued)	**Indicative content** • As parachute opens (at B) the upwards force increases • Along BC the velocity is decreasing at a non-constant rate • The drag is greater than weight (negative gradient) • The drag is decreasing (curved line) • Eventually the drag force balances the weight • No acceleration so line is horizontal		

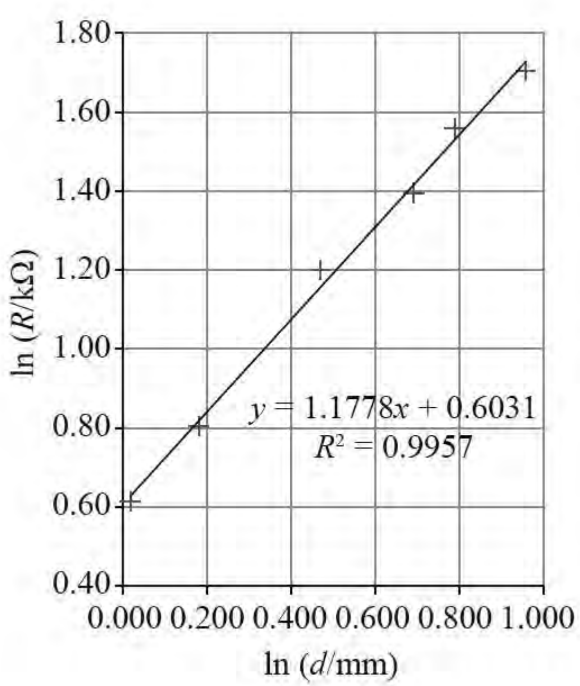
(Total for Question 9 = 10 marks)

Question number	Acceptable answers	Additional guidance	Mark
10 (a)	A description that makes reference to the following points: • g is directly proportional to r up to R_0 **(1)** • and then g decreases with increasing r **(1)** • where g is proportional to the inverse of the square of r **(1)**		**3**
10 (b)	• Force on object = *mg* (local *g*) **(1)** • Force is proportional to displacement **(1)** • Force acts in the opposite direction to the displacement **(1)** • Therefore we can say $F = -kx$, so the condition for SHM is met and the prediction is correct **(1)**		**4**
10 (c)(i)	**Either** • When $x = R_0$, $F = GMm/R_0^2$ **(1)** • $F = GMmR_0/R_0^3$ so $k = m\omega^2 = GMm/R_0^3$ **(1)** • Use of $T = 2\pi/\omega$ **(1)** • $T^2 = 4\pi^2/\omega^2 = 4\pi^2 R_0^3/GM$ So $T = 2\pi\sqrt{(R_o^3/GM)}$ **(1)** **OR** • From graph $F = -(g/R_o)r$ **(1)** • From which $\omega = \sqrt{(g/R_0)}$ **(1)** • Use of $T = 2\pi/\omega$ **(1)** • So $T = 2\pi\sqrt{(R_o/g)}$ **(1)**		**4**

Question number	Acceptable answers	Additional guidance	Mark
10 (c)(ii)	**Either** Centripetal force = $mv^2/R_0 = GMm/R_0^2$ **(1)** • $4\pi^2 R_0^2/ T^2R_0 = GM/R_0^2$ **(1)** • $T^2 = 4\pi^2/\omega^2 = 4\pi^2 R_0^3/GM$ So $T = 2\pi\sqrt{(R_o^3 /GM)}$ **(1)** **OR** • $mg = mv^2/R_0 = m\,\omega^2R_0$ **(1)** • So $\omega = \sqrt{(g/R_0)}$ **(1)** • $T = 2\pi/\omega = 2\pi\sqrt{(R_0/g)}$ **(1)**		**3**

(Total for Question 10 = 14 marks)

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>11 (a)</td><td>An explanation that makes reference to the following points:
• Resistance increases with decreasing intensity (1)
• As distance increases light intensity decreases so resistance increases (1)</td><td></td><td>2</td></tr>
<tr><td>11 (b)</td><td>An explanation that makes reference to the following points:
• Shows expansion $\ln R = p \ln(d) + \ln(k)$ (1)
• Compares with $y = mx + c$ and states that the gradient is p which is constant (1)</td><td></td><td>2</td></tr>
<tr><td>11 (c)(i)</td><td>• Ln values correct and to 3 or 4 SF (1)
<table>
<tr><th>d/m</th><th>R/kΩ</th><th>ln (d/m)</th><th>ln (R/kΩ)</th></tr>
<tr><td>1.00</td><td>1.79</td><td>0.000</td><td>0.582</td></tr>
<tr><td>1.20</td><td>2.24</td><td>0.182</td><td>0.806</td></tr>
<tr><td>1.60</td><td>3.32</td><td>0.470</td><td>1.200</td></tr>
<tr><td>2.00</td><td>4.04</td><td>0.693</td><td>1.396</td></tr>
<tr><td>2.20</td><td>4.70</td><td>0.788</td><td>1.548</td></tr>
<tr><td>2.60</td><td>5.50</td><td>0.956</td><td>1.705</td></tr>
</table>
• Labels and unit (1)
• Scales (1)
• Plots (1)
• Line of best fit (1)</td><td>See marking guidance for graph plotting</td><td>5</td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
11 (c)(i) (continued)			
11 (c) (ii)	• Finds gradient with large triangle – at least half the plotted length **(1)** • 1.13 < p < 1.23 to 2/3 SF and no units **(1)** • Obtains k = 1.8 **(1)** • States relationship between R and d **(1)**		**4**

(Total for Question 11 = 13 marks)

Question number	Acceptable answers	Additional guidance	Mark
12 (a)(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces $F_e = 8.1 \times 10^{-8}$ N $F_g = 3.6 \times 10^{-47}$ N **(1)** • Ratio = 2×10^{39} or 5×10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
12 (a)(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2×10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ F}m^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**
12 (b)	• Calculates wavelength λ (circumference) **(1)** • Use of $p = h/\lambda$ **(1)** • $v = 2.2 \times 10^6$ m s^{-1} **(1)**	Example of calculation: $\lambda = 2\pi r = 2\pi \times 5.3 \times 10^{-11}\text{m} = 3.33 \times 10^{-10}$ m $\lambda = h/mv$ so $v = h/m.$ $v = 6.63\times10^{-34}$ J s/(9.1×10^{-31} kg$\times3.33\times10^{-10}$ m) $v = 2.188 \times 10^6$ m s^{-1}	**3**

(Total for Question 12 = 10 marks)

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>13 (a)</td><td>An explanation that makes reference to the following points:
Resonance is occurring… (1)
…when the driving frequency/forced vibration (at walking frequency) matches the natural frequency … (1)
…energy transfer is maximum (1)
Supporting the observation that the amplitude rapidly increases (1)</td><td></td><td>4</td></tr>
<tr><td>13 (b)(i)*</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

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Question number	Acceptable answers	Additional guidance	Mark
13 (b)(i)* (continued)	**Indicative content** • Determine the natural frequency by displacing the tea in the cup and measuring the time for oscillations • Time (5 to 10 or 'suitable number' if test run mentioned) full oscillations and divide by the number • Carry the tea for a known volume of tea for fixed number of steps at a steady pace • Determine the frequency of the gait • Measure the quantity of tea remaining • Repeat for other walking paces		
13 (b)(ii)	A description that makes reference to the following points: • Plot volume of remaining tea against walking frequency **(1)** • Determine whether there is a relationship between step frequency and spillage **(1)** • If there is, determine whether maximum spillage occurs at or near the natural frequency **(1)**		**3**

(Total for Question 13 = 13 marks)