Mark Scheme

Q1.

Question Number	Answer		Mark
(a)	• Length/height of wooden rod	(1)	
	• Distance from the rod to the light gate	(1)	2
(b)	• $v = \frac{\text{length of rod}}{\text{time (to pass through light gate)}}$	(1)	
	• Repeat (at each height) and (calculate) an average	(1)	2
(c)	• Repeat at different (release) heights (above the light gate and calculate v for each height)	(1)	
	• States an appropriate graph to draw	(1)	
	• Corresponding description of how to obtain the acceleration from the gradient	(1)	3
	Total for question		7

Graph	$s - v^2$	$v^2 - s$	$2s - v^2$	$v^2 - 2s$	$v^2/2 - s$	$s - v^2/2$
a	1/(2×gradient)	gradient/2	1/gradient	gradient	gradient	1/gradient
Gradient	$1/2a$	$2a$	$1/a$	a	a	$1/a$

Q2.

Question Number	Answer		Mark
	• Reference to $s = ut + ½ at^2$ with $u = 0$	(1)	
	• Correct variable labels on graph axes to give a straight line through origin.	(1)	
	• Reference to time in s and distance in m (this can be taken from the axes labels or a suitable unit conversion)	(1)	
	• Straight line through origin.	(1)	
	• Correct method to determine g using their graph.	(1)	
			(5)

Q3.

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Question Number	Acceptable Answer		Additional Guidance	Mark
1(a)	• calculates mean value of time • use of $s = ut + \frac{1}{2}at^2$ • a = 9.5 m s^{-2} to 2/3 sf	(1) (1) (1)	Example of calculation: Average time, t_{av} = (0.45 s +0.51 s + 0.43 s)/3 = 0.46 s $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 1.00\,\text{m}}{(0.46\,\text{s})^2} = 9.45\,\text{m}\,\text{s}^{-2}$	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
1(b)	• calculates % uncertainty in t using range / half-range **Or** calculates uncertainty in s using precision of instrument • doubles uncertainty in t • uncertainty in a = 18 %	(1) (1) (1)	Example of calculation: Uncertainty in t = (0.04/0.46) × 100% = 8.7 % Uncertainty in t^2 = 2 × 8.7 % = 17.4 % Uncertainty in s = (0.01/1.00)× 100 % = 1 % Uncertainty in g = 18.4 %	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
1(c)	• % uncertainty in t would decrease • longer times identified as key factor in reducing uncertainty in value obtained for *g*	(1) (1)		**(2)**

(Total for Question 1 = 8 marks)

Q4.

01.1	Clear identification of distance from centre of sphere to right hand end of mark, or to near r.h.end of mark ✓		1
01.2	0.393 (s) ✓	Accept 0.39 (s)	1
01.3	For 10 oscillations percentage uncertainty = $\frac{0.1}{15.7}$ = 0.00637 ≡ 0.64% ✓ same for the ¼ period ✓		2
01.4	Identifies anomaly [0.701] ✓ and calculates mean distance = 0.759 (m)✓	Allow 1 max if anomaly included in calculation giving 0.750 (m)	2
01.5	Largest to smallest variation = 0.026 (m) Absolute uncertainty = 0.013 (m)✓		1
01.6	Use of $g = \frac{2d}{t^2}$ leading to 9. 83 (m s^{-2}) ✓ percentage uncertainty in distance = 1.7%✓ Total percentage uncertainty = 1.7 + 2 x 0.64 = 3.0% Absolute uncertainty = 0.30 (m s^{-2}) ✓ [g = 10.0 ± 0.3 m s^{-2}]	Allow 9.98 (m s^{-2}) if 0.39 used Ecf if anomaly included in mean in 1.4 Expressed sf must be consistent with uncertainty calculations	3

01.7	suggests one change ✓ Sensible comment about change or its impact on uncertainty ✓ eg Use pointed mass not sphere Because this will give better defined mark OR because the distance determination has most impact on uncertainty OR Time more swings/oscillations As this reduces the percentage uncertainty in timing OR longer/heavier bar would take a greater time to swing to the vertical increasing t and s and reducing the percentage uncertainty in each	If data logger proposed, it must be clear what sensors are involved and how the data are used.	2

01.8	[$s = \frac{g}{2}t^2$] plot graph of s against t^2 or $\sqrt{s}$ against t ✓ calculate the gradient ✓ the gradient is $g/2$ or $\sqrt{(g/2)}$ ✓	Accept: plot s against $t^2/2$ or plot $2s$ against t^2: calculate the gradient in both cases gradient gives g Allow 1 max for answer that evaluates g for each data point and averages	3

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
	• calculation of gradient of the graph • Use of $s = \frac{1}{2}at^2$ to obtain value for g • Total uncertainty = 7 % • Calculation of % difference **Or** Range of calculated g • Judgment on accuracy of experiment with reason	(1) (1) (1) (1) (1)	MP2: use of $\frac{2}{\text{gradient}}$ MP3: percentage uncertainty = 3 % + 3 % + 1 % MP5: e.g. comparison of total uncertainty with % difference **Or** comparison of calculated range with 9.81 m s^{-2} <u>Example of calculation</u> Gradient = $\frac{0.385\ s^2 - 0.06\ s^2}{1.8\ m - 0.4m} = 0.232\ s^2\ m^{-1}$ $g = \frac{2}{0.232\ s^2\ m^{-1}} = 8.67\ m\ s^{-2}$ Percentage difference=$\left(\frac{9.81\ m\ s^{-2} - 8.67\ m\ s^{-2}}{9.81\ m\ s^{-2}}\right) \times 100 =$ 12 %	5

Question			Answer	Marks	Guidance
6	(a)	(i)	0.22(1), 0.26(0), 0.30(2) or 0.30(3)	2	all correct = 2, 2 correct = 1
		(ii)	plotting (2) line (1)	3	all correct = 2, 2 correct = 1 (ecf) tolerance on each point = ± 0.5 small scale division by eye: NOT through origin
	(b)	(i)	considering when t = 0 (1) s should = 0 (1)	2	
		(ii)	triangle base/ Δt must be at least 0.05 s (1) expected gradient = 4.7 to 5.0 (1)	2	Must have appropriate triangle or pair of data points. ecf own line
		(iii)	g = double gradient (9.6 to 10.0) (1) unit: m s^{-2} (1)	2	ecf allow N kg^{-1}
	(c)	(i)	t is too big/s too small (1) plausible suggestion for why (1)	2	Owtte e.g t should be smaller or s should be bigger
		(ii)	With respect to s gradient **does not** change (1) idea of ALL values shifted equally(1) **OR** With respect to t the gradient **does** change (1) constant error in t affects values of t^2 by different amounts (1)	2	
			Total	**15**	

7

(a) Both t_m values correct: 0.404, 0.429
AND
Both t_m^2 values correct: 0.163, 0.184 ✓

Exact values required for the mark.

(b) Both plotted points to nearest mm ✓
Best line of fit to points ✓
The line should be a straight line with approximately an equal number of points on either side of the line.
2

(c) Large triangle drawn (at least 8 cm × 8 cm) ✓
Correct values read from graph ✓
Gradient value in range 0.190 to 0.222 ✓
Allow 2 or 3 sf for gradient
3

(d) g = 9.71 (ms^{-2}) or correct value from gradient value in **(c)** ✓.

(The answer must be in the range 9.0 to 10.5 (ms^{-2})).
Allow 2 or 3 sf.
Unit not required
1

(e) $\% \ difference = \frac{(9.81 - 9.71)}{9.81} \times 100 = 1.02$

OR correct computation using value from **(d)** ✓
If the candidate's value is exactly 9.81, then a statement that there is no (or zero) percentage difference is acceptable.
No sf penalty.
NB. Allow an answer from a calculation with either the candidate's value or the accepted value as the denominator in the equation.
1

(f) 0.001 s✓ (half the spread)
(Must have unit).
1

(g) $g = 2s/t_m^2$ ✓
= 2 × 0.300/0.245^2 ✓
= 10.0 (or 10.00) ms^{-2} ✓
Unit required and 3 or 4sf for the last mark.
3

(h) % uncertainty in s = 0.33 **and**
% uncertainty in t_m = 0.41 ✓

*Allow ecf from part **(f)**.*

% uncertainty in g
= 0.33 + (2 × 0.41) = 1.15 ✓

Allow ecf at each stage of calculation.

Uncertainty in g
= 10.0 × 1.15/100 = 0.12 m s^{-2} or 0.1 m s^{-2} ✓

*Allow ecf from part **(g)**.*

(allow 1 or 2 sf only)
(Must have unit for 3rd mark).

3

(i) (a) Use spherical objects of different mass **and** determine mass with balance ✓

Annotate the script with the appropriate letter at the point where the mark has been achieved.

(b) Would need **same diameter** spherical objects for fair comparison (same air resistance etc) ✓

(c) Time spherical object falling through same height **and** compare times

*Alternative for **(c)**:*
i.e. repeat whole of experiment, plot extracted values of g against mass. Horizontal line expected, concluding acceleration same for different masses.

3

[18]

Part	Mark	Expected Answer	Additional Guidance
(a)	A1	$\frac{2}{g}$	
(b)	T1	t^2 / s^2	Column heading: allow t^2 (s^2) or t^2in s^2 Do not allow $(t / s)^2$
	T2	0.12 or 0.123 0.15 or 0.152 0.18 or 0.185 0.20 or 0.203 0.24 or 0.240 0.27 0r 0.270	Must be to two or three significant figures. A mixture of 2sf and 3sf is allowed.
	U1	± 0.007 to ± 0.010 (allow ± 0.011)	Allow more than one significant figure.
(c) (i)	G1	Six points plotted correctly.	Must be within half a small square. Use transparency. Ecf allowed from table.
	U2	Error bars in t^2 plotted correctly.	Check first and last point. Must be accurate within half a small square.
(c) (ii)	G2	Line of best fit.	If points are plotted correctly then lower end of line should pass between (0.60, 0.116) and (0.60, 0.123) **and** upper end of line should pass between (1.30, 0.268) and (1.30, 0.272). Allow ecf from points plotted incorrectly – examiner judgement. Five good trend plots needed.
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through <u>all</u> the error bars.	Line should be clearly labelled or dashed. Should pass from top of top error bar to bottom of bottom error bar **or** bottom of top error bar to top of bottom error bar. Mark scored only if error bars are plotted.
(c) (iii)	C1	Gradient of best fit line.	The triangle used should be greater than half the length of the drawn line. Check the read offs. If incorrect circle and write in correct value. Work to half a small square. Do not penalise POT.
	U3	Uncertainty in gradient.	Method of determining absolute error Difference in worst gradient and gradient.
(d)	C2	g = 2/gradient	Gradient must be used. Allow ecf from **(c) (iii)**
	U4	Method of determining uncertainty in *g.*	Uses worst gradient and finds difference. Allow fractional error methods. Do not check calculation.

	C3	Unit of *g*: **m s^{-2}**	Accept **N kg^{-1}**
(e) (i)	C4	21.9 – 23.5	Answer must be in range given to 2 or 3sf. Allow 22 or 23.
(e) (ii)	U5	Method for percentage uncertainty in *b*.	Calculates percentage uncertainty in t^2 and adds to percentage uncertainty in gradient or *g*. Allow ecf from **(c) (iii)** and/or **(d)**.

[Total: 15]

Uncertainties in Question 2

(c) (iii) Gradient [U3]

1. Uncertainty = gradient of line of best fit – gradient of worst acceptable line
2. Uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)

(d) *g* [U4]

1. Uncertainty = *g* from gradient - *g* from worst acceptable line
2. $\frac{\Delta g}{g} = \frac{\Delta gradient}{gradient}$

(e) *b* [U5]

1. Substitution method to find worst acceptable *g* using
   either largest *g* × 2.22^2
   or smallest *g* × 2.20^2
   then determines percentage uncertainty
2. 0.9% + percentage uncertainty in gradient or percentage uncertainty in *g*
3. $\frac{\Delta b}{b} \times 100 = \left(\frac{\Delta g}{g} + 2\frac{\Delta t}{t} \right) \times 100$