3.9 A-Level Physics: Required Practicals and Uncertainties: 30-minute Pack

AQA 7408 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A student investigates how the period T of a simple pendulum depends on its length L, to test the relationship $T = k L^n$ and, from it, to find a value for g.

L (m): 0.20, 0.40, 0.60, 0.80, 1.00

T (s): 0.897, 1.269, 1.554, 1.794, 2.006

log10(L): -0.699, -0.398, -0.222, -0.097, 0

log10(T): -0.047, 0.103, 0.191, 0.254, 0.302

(a) Show that taking logarithms of both sides of $T = k L^n$ gives a straight-line relationship between log10(T) and log10(L), and state what the gradient and the y-intercept of this line represent. **(3)**

(b) Show that, taking $g = 9.81$ m s^{-2} and using the Physics Equations Sheet equation for the period of a simple pendulum, $T = 1.55$ s (3 significant figures) when $L = 0.600$ m. **(2)**

(c) The line of best fit through the log10(T) against log10(L) data has gradient 0.500 and y-intercept 0.302. Determine the value of n, and hence use the y-intercept to find k and a value for g. (Hint: since $T = k L^n$ with $n = 0.5$, $k = 2\pi / \sqrt{g}$.) **(5)**

(d) Explain why the period is timed over many oscillations (e.g. 20) rather than a single swing, and suggest, without changing the apparatus, one way the percentage uncertainty in the final value of g could be further reduced. **(3)**

(Total for Question 1 is 13 marks)

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2 A student investigates stationary waves on a stretched string. A vibration generator at one end and a fixed pulley at the other keep a constant tension in the string; for each length L between the generator and the pulley, the student adjusts the frequency until a clear standing-wave pattern (one loop) is seen, and records the resonant frequency f.

L (m): 0.20, 0.30, 0.40, 0.50, 0.60

f (Hz): 150, 100, 75, 60, 50

(a) Explain, in terms of superposition of waves, how a stationary wave pattern is produced on the string. **(2)**

(b) Using f = v / (2L) (from the Physics Equations Sheet, for the fundamental mode), calculate f x L for each pair of values in the table, and comment on what this shows about the relationship between f and L. **(3)**

(c) The student plots f (y-axis) against 1/L (x-axis). State the shape of this graph and what physical quantity is given by its gradient. **(2)**

(d) The wave speed on a stretched string is given by $v = \sqrt{T/\μ}$ (Physics Equations Sheet), where T is the tension and μ is the mass per unit length. Using $v = 60\ m\ s^{-1}$ found in part (b) and a tension of T = 4.5 N, calculate μ. **(3)**

(e) State and explain the effect on the resonant frequency, for a fixed length L, of increasing the tension in the string. **(2)**

(Total for Question 2 is 12 marks)

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Mark scheme · 3.9 A-Level Physics: Required Practicals and Uncertainties: 30-minute Pack

Question 1

(a) log10(T) = log10(k) + n log10(L) (correct application of log rules to $T = k L^n$) **M1**

(a) gradient of the log10(T) against log10(L) graph = n **A1**

(a) y-intercept (value of log10(T) at log10(L) = 0) = log10(k) **A1**

(a) Answer: log10(T) = log10(k) + n log10(L); gradient = n, y-intercept = log10(k).

(b) $T = 2\pi\sqrt{0.600/9.81}$ (correct substitution) **M1**

(b) 1.55 s cso (answer given) **A1**

(b) Answer: 1.55 s

(c) n = 0.500 (the gradient), confirming T is proportional to the square root of L **B1**

(c) $k = 10^{\text{y-intercept}}$ (correct rearrangement of log10(k) = y-intercept) **M1**

(c) k = 2.00 s $m^{-0.5}$ (awrt 2.00) cao **A1**

(c) rearranges $k = 2\pi / \sqrt{g}$ to give $g = (2\pi / k)^2$, and substitutes their k **M1**

(c) g = 9.9 m s^{-2} (accept any value in the range 9.7 to 10.0 m s^{-2}, due to rounding in k) **A1**

(c) Answer: n = 0.500; k = 2.00 s $m^{-0.5}$; g is approximately 9.9 m s^{-2} (accept 9.7 to 10.0 m s^{-2}).

(d) the fixed absolute uncertainty from human reaction time is divided by the number of oscillations timed, greatly reducing the percentage uncertainty in the period T oe **B1**

(d) use the largest practical range of pendulum lengths L (including the longest achievable length) when taking readings for the graph oe **B1**

(d) a longer L gives a longer T for the same fixed reaction-time uncertainty, reducing its percentage uncertainty, and a wider range of L values on the log-log graph reduces the effect of any single anomalous point on the gradient (and hence on g) oe **B1**

(d) Answer: Timing many oscillations divides the fixed reaction-time uncertainty across all of them, reducing its percentage effect; using the widest practical range of L (including longer lengths) further reduces the percentage uncertainty in g.

Question 2

(a) a progressive wave travels along the string and is reflected at the fixed end (pulley), so two waves of the same frequency and amplitude travel in opposite directions along the string oe **B1**

(a) these waves superpose; at the resonant frequency this produces a stable pattern of fixed nodes (no displacement) and antinodes (maximum displacement) oe **B1**

(a) Answer: Waves travelling in opposite directions (incident and reflected) superpose to form a fixed pattern of nodes and antinodes.

(b) calculates f x L for at least three pairs: 0.20x150=30, 0.30x100=30, 0.40x75=30, 0.50x60=30, 0.60x50=30 **M1**

(b) all five products are equal (constant at 30 m s^{-1}, within experimental variation) **A1**

(b) this confirms f is inversely proportional to L ($f = v/(2L)$), with wave speed v = 2 x 30 = 60 m s^{-1} **A1**

(b) Answer: fL = 30 m/s for every row, confirming f is inversely proportional to L; wave speed v = 60 m/s

(c) a straight line through the origin **B1**

(c) gradient = v/2, so the wave speed v on the string is twice the gradient oe **B1**

(c) Answer: A straight line through the origin; gradient = v/2, so v is twice the gradient.

(d) rearranges to $\mu = T / v^2$ **M1**

(d) $4.5 / 60^2$ (correct substitution, ft their v) **M1**

(d) 1.25 x 10^{-3} kg m^{-1} (awrt 1.25) cao **A1**

(d) Answer: 1.25 x 10^{-3} kg m^{-1}

(e) increasing T increases v, since $v = \sqrt{T/\μ}$ **B1**

(e) with L fixed, f = v/(2L), so increasing v increases the resonant frequency f oe **B1**

(e) Answer: The resonant frequency increases, because increasing tension increases the wave speed v, and f = v/(2L) with L fixed.

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