# 3.1 Measurements and their Errors: 1-hour Pack

AQA 7408 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

**Answer ALL questions. Show all your working.**

**1** Reading an instrument scale correctly is a fundamental practical skill.

**(a)** A micrometer screw gauge has a resolution of 0.01 mm. For a particular reading, the main scale shows 5.5 mm and the rotating thimble scale, on which each division represents 0.01 mm, is aligned with the line labelled 23. Calculate the diameter reading shown, and state the absolute uncertainty in this single reading. **(3)**

**(b)** A vernier caliper has a resolution of 0.02 mm. For a particular reading, the main scale shows 12 mm and the 4th line on the vernier scale is the one that aligns exactly with a main scale line. Calculate the diameter reading shown, and state the absolute uncertainty in this single reading. **(3)**

**(Total for Question 1 is 6 marks)**

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**2** A student measures the length of a metal rod using vernier calipers of resolution 0.1 mm, obtaining a reading of 45.0 mm.

**(a)** Calculate the percentage uncertainty in the single reading of 45.0 mm. **(2)**

**(b)** The student instead repeats the measurement 5 times, obtaining: 45.0 mm, 45.2 mm, 44.8 mm, 45.1 mm, 44.9 mm. Calculate the mean length and the absolute uncertainty using the range method (half the range of the readings). **(3)**

**(c)** Explain why the uncertainty found in part (b) is greater than the uncertainty found in part (a). **(2)**

**(Total for Question 2 is 7 marks)**


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**3** Errors in measurement can be systematic or random.

**(a)** State one difference between a systematic error and a random error. **(2)**

**(b)** A newton-meter (spring balance) reads 0.20 N when nothing is hung from it. Identify the type of error this illustrates and explain how the student should account for it. **(2)**

**(c)** A student times 20 complete oscillations of a pendulum, rather than timing a single oscillation, to determine its period. Explain how timing 20 oscillations reduces the percentage uncertainty in the period, compared with timing a single oscillation. **(3)**

**(Total for Question 3 is 7 marks)**


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**4** The percentage uncertainty in a calculated quantity depends on how that quantity is combined mathematically from its measured inputs: percentage uncertainties are added for a product or quotient, and multiplied by the power for a term raised to a power (including a square root, which multiplies the percentage uncertainty by 1/2).

**(a)** A heating element has a potential difference V = 6.0 ± 0.1 V across it and a resistance R = 15.0 ± 0.3 ohm. Calculate the percentage uncertainty in V and the percentage uncertainty in R. **(2)**

**(b)** The power dissipated is given by $P = V^2 / R$. Calculate the percentage uncertainty in P, and hence state the power P with its absolute uncertainty, to an appropriate number of significant figures. **(3)**

**(c)** A mass m = 0.250 ± 0.005 kg is attached to a spring of spring constant k = 18.0 ± 0.5 N/m. Calculate the percentage uncertainty in m and the percentage uncertainty in k. **(2)**

**(d)** The period of oscillation is given by $T = 2 \times \pi \times \sqrt{m/k}$. Calculate the percentage uncertainty in T, and hence state the period T with its absolute uncertainty, to an appropriate number of significant figures. **(3)**

**(Total for Question 4 is 10 marks)**

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**5** A student uses a simple pendulum to determine the acceleration due to gravity, g, using $T = 2 \times \pi \times \sqrt{l/g}$, which rearranges to $g = 4 \times \pi^2 \times l / T^2$. The pendulum length is l = 0.850 ± 0.002 m. The time for 20 complete oscillations is measured as 37.0 ± 0.4 s.

**(a)** Show that the period, T, of the pendulum is 1.85 s. **(2)**

**(b)** Calculate the percentage uncertainty in the time for 20 oscillations, and hence state the percentage uncertainty in the period, T. **(3)**

**(c)** Calculate the percentage uncertainty in $T^2$. **(1)**

**(d)** The percentage uncertainty in l is 0.24%. Calculate the percentage uncertainty in g. **(2)**

**(e)** Calculate the value of g and its absolute uncertainty, to an appropriate number of significant figures. **(4)**

**(f)** The accepted value of g is 9.81 $m/s^2$. Comment on whether the student's result in part (e) is consistent with the accepted value. **(2)**

**(Total for Question 5 is 14 marks)**


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# Mark scheme · 3.1 Measurements and their Errors: 1-hour Pack

## Question 1

(a) thimble contribution = 23 x 0.01 mm = 0.23 mm **M1**

(a) diameter = 5.5 + 0.23 = 5.73 mm (cao) **A1**

(a) uncertainty = ± 0.005 mm (half the resolution) **B1**

**(a) Answer: 5.73 ± 0.005 mm**

(b) vernier contribution = 4 x 0.02 mm = 0.08 mm **M1**

(b) diameter = 12 + 0.08 = 12.08 mm (cao) **A1**

(b) uncertainty = ± 0.01 mm (half the resolution) **B1**

**(b) Answer: 12.08 ± 0.01 mm**

## Question 2

(a) identifies absolute uncertainty as half the resolution: ± 0.05 mm **M1**

(a) 0.11% (awrt) **A1**

**(a) Answer: 0.11%**

(b) mean = (45.0 + 45.2 + 44.8 + 45.1 + 44.9) / 5 = 45.0 mm **M1**

(b) uncertainty = half the range = (45.2 - 44.8) / 2 = 0.2 mm **M1**

(b) 45.0 ± 0.2 mm (cao) **A1**

**(b) Answer: 45.0 ± 0.2 mm**

(c) the repeated readings show random variation (e.g. from positioning the calipers slightly differently each time) that a single reading cannot reveal **M1**

(c) this random variation between repeats is larger than the instrument's resolution alone, so the range-based uncertainty is greater than the resolution-based uncertainty **A1**

**(c) Answer: Repeating the measurement reveals random variation between readings that is bigger than the instrument's resolution, so the spread-based uncertainty in (b) exceeds the resolution-based uncertainty in (a).**

## Question 3

(a) a systematic error affects all readings by the same amount and in the same direction (consistently too high or too low), and is not reduced by repeating/averaging **B1**

(a) a random error causes readings to scatter unpredictably above and below the true value, and its effect can be reduced by repeating readings and averaging **B1**

**(a) Answer: Systematic errors shift every reading consistently in the same direction and cannot be reduced by averaging; random errors scatter readings unpredictably and can be reduced by taking repeats and averaging.**

(b) this is a systematic (zero) error **B1**

(b) the student should subtract 0.20 N from every subsequent reading (or re-zero/calibrate the instrument before use) **B1**

**(b) Answer: It is a systematic (zero) error; the student should subtract 0.20 N from every reading taken (or zero the instrument before use).**

(c) the absolute uncertainty from human reaction time (e.g. approximately ± 0.2 s) when starting/stopping the stopwatch is essentially the same whichever quantity is timed **M1**

(c) timing 20 oscillations gives a total time about 20 times larger than timing 1 oscillation, while the absolute uncertainty stays roughly fixed **M1**

(c) so the percentage uncertainty (absolute uncertainty / measured value) is reduced by a factor of about 20 compared with timing a single oscillation **A1**

**(c) Answer: The fixed reaction-time uncertainty becomes a much smaller fraction of the (about 20 times larger) total time, so the percentage uncertainty in the period is roughly 20 times smaller than if a single oscillation were timed.**

## Question 4

(a) percentage uncertainty in V = (0.1/6.0) x 100 = 1.7% (awrt) **B1**

(a) percentage uncertainty in R = (0.3/15.0) x 100 = 2.0% **B1**

**(a) Answer: V: 1.7%; R: 2.0%**

(b) since V is squared, its percentage uncertainty doubles: %unc(P) = (2 x 1.67%) + 2.0% = 5.3% (ft from a) **M1**

(b) $P = V^2/R = 6.0^2/15.0 = 2.4$ W **M1**

(b) absolute uncertainty = 2.4 x 0.053 = 0.13, so P = (2.4 ± 0.1) W (ft, awrt) **A1**

**(b) Answer: P = (2.4 ± 0.1) W**

(c) percentage uncertainty in m = (0.005/0.250) x 100 = 2.0% **B1**

(c) percentage uncertainty in k = (0.5/18.0) x 100 = 2.8% (awrt) **B1**

**(c) Answer: m: 2.0%; k: 2.8%**

(d) for a square root, the percentage uncertainty is multiplied by 1/2: %unc(T) = 0.5 x (2.0% + 2.8%) = 2.4% (ft from c) **M1**

(d) $T = 2 \times \pi \times \sqrt{0.250/18.0} = 0.740$ s **M1**

(d) absolute uncertainty = 0.740 x 0.024 = 0.018, so T = (0.740 ± 0.018) s (ft, awrt) **A1**

**(d) Answer: T = (0.740 ± 0.018) s**


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## Question 5

(a) T = (time for 20 oscillations) / 20 = 37.0/20 **M1**

(a) 1.85 s (cso, answer given) **A1**

**(a) Answer: T = 1.85 s**

(b) percentage uncertainty in total time = (0.4/37.0) x 100 = 1.1% **M1**

(b) dividing by the constant 20 to find T does not change the percentage uncertainty **M1**

(b) percentage uncertainty in T = 1.1% (ft) **A1**

**(b) Answer: 1.1%**

(c) 2.2% (ft from b, doubled for the squared term) **B1**

**(c) Answer: 2.2%**

(d) for a product/quotient, percentage uncertainties add: %unc(g) = %unc(l) + %unc($T^2$) **M1**

(d) 2.4% (awrt, ft from c) **A1**

**(d) Answer: 2.4%**

(e) correct substitution: $g = 4 \times \pi^2 \times 0.850 / (1.85)^2$ **M1**

(e) g = 9.80 m/s$^2$ (awrt) **M1**

(e) absolute uncertainty = 9.80 x 0.024 = 0.24 m/s$^2$ (ft from d) **M1**

(e) g = (9.80 ± 0.24) m/s$^2$ (awrt, appropriate s.f.; accept (9.8 ± 0.2) m/s$^2$) **A1**

**(e) Answer: g = (9.80 ± 0.24) m/s$^2$**

(f) the range given by the result is 9.80 - 0.24 = 9.56 m/s$^2$ to 9.80 + 0.24 = 10.04 m/s$^2$ (ft from e) **B1**

(f) since 9.81 m/s$^2$ lies within this range, the result is consistent with the accepted value **B1**

**(f) Answer: Yes; 9.81 m/s$^2$ lies within the range 9.56 m/s$^2$ to 10.04 m/s$^2$, so the result is consistent with the accepted value.**


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