1. Physical Quantities and Units

1.3 Errors and uncertainties

Paper 2

Marking Scheme

Q1.

(b)(ii)	percentage uncertainty = $3 + 2 \times (5 / 1300) \times 100$	**C1**
	$= 3 + 2 \times 0.38$ $= (\pm)\ 4\%$	**A1**

Q2.

(b)(ii)	$(0.001 / 0.243)$ **or** $(0.01 / 5.41)$ **or** $(0.01 / 11.09)$ **or** $(0.01 / 1.62)$	**C1**
	$(\Delta\rho / \rho) = (\Delta m / m) + (\Delta x / x) + (\Delta y / y) + (\Delta z / z)$ $= (0.001 / 0.243) + (0.01 / 5.41) + (0.01 / 11.09) + (0.01 / 1.62)$ $(= 0.013)$	**C1**
	percentage uncertainty in ρ $= 0.013 \times 100$ $= 1.3\%$ (allow 1 s.f. answer of 1%)	**A1**
(c)	zero error (on calipers / balance) **or** incorrect calibration (of calipers / balance)	**B1**

Q3.

(c)	R contributes $4 \times 2\%$ **or** 8% (and L contributes 2%) so R contributes more (to the percentage uncertainty in k)	**B1**

Q4.

(b)(i)	$r = [(3 \times 28) / 4\pi]^{1/3}$ $= 1.9$ cm	**A1**
(b)(ii)	percentage uncertainty in $V = (0.5 / 28) \times 100$ $(= 1.79\%)$	**C1**
	percentage uncertainty in $r = 1.79 / 3$ $= 0.6\%$	**A1**

Q5.

(b)(i)	percentage uncertainty $= 2.1 + 0.6 + (1.5 \times 2)$	**C1**
	$= 5.7\%$	**A1**
(b)(ii)	absolute uncertainty $= (5.7 / 100) \times 8.245 \times 10^9$ $(= 4.7 \times 10^8$ Pa or 0.47×10^9 Pa$)$	**C1**
	$E = (8.2 \pm 0.5) \times 10^9$ Pa	**A1**

Q6.

(b)(i)	the measurements have a small range	**B1**
(b)(ii)	(average of the) measurements not close to the true value	**B1**
(c)(i)	percentage uncertainty $= (3 + 5 + 4) / 2$	**C1**
	$= 6\%$	**A1**
(c)(ii)	absolute uncertainty $= (6 / 100) \times 15.0$ $= 0.9\ \text{m s}^{-1}$	**A1**

Q7.

(c)(i)	$84 \times 10^3 = v^3 \times 0.56$	**C1**
	$v = 53$ m s^{-1}	**A1**
(c)(ii)	percentage uncertainty = (5% + 7%) / 3 (= 4%) **or** fractional uncertainty = (0.05 + 0.07) / 3 (= 0.04)	**C1**
	absolute uncertainty = 0.04×53 = (±) 2 m s^{-1}	**A1**

Q8.

(b)(i)	absolute uncertainty = $4.0 \times (5 / 100)$ = (±) 0.2 cm	**B1**
(b)(ii)	percentage uncertainty = $2 + 4 + (5 \times 2)$	**C1**
	= (±) 16%	**A1**

Q9.

(b)(i)	(vernier/digital) calipers	**B1**
(b)(ii)	percentage uncertainty = $(0.0004 / 0.0420) \times 100$ = 1%	**A1**
(c)(ii)	$(\Delta\rho / \rho) = (\Delta M / M) + 2(\Delta r / r) + (\Delta L / L)$	**C1**
	percentage uncertainty = $[(0.001 / 1.072) + 2 \times (0.0004 / 0.0420) + (0.0001 / 0.1242)] (\times 100)$	**C1**
	= $0.09\% + 2 \times 0.95\% + 0.08\%$ = 2%	**A1**
(c)(iii)	$\rho = (1.072 \times 0.0420^{-2}) / (2.094 \times 0.1242)$ = 2337 (kg m^{-3})	**C1**
	$\Delta\rho = 0.021 \times 2337$ = 49 (kg m^{-3})	**C1**
	ρ = (2340 ± 50) kg m^{-3}	**A1**

Q10.

(c)(i)	percentage uncertainty = $3.5 + (3.0 \times 2) + 2.5 + 2.0$	**C1**
	= 14%	**A1**
(c)(ii)	absolute uncertainty = $4.1 \times 10^{-7} \times 14 / 100$ = 6×10^{-8} Ω m	**A1**

Q11.

(b)(ii)	**1.** e.g. reading scale from different angles (wrongly) interpolating between scale readings/divisions	**B1**
	2. e.g. zero error wrongly calibrated scale	**B1**

Q12.

(b)(i)	$E = FL / Ax$	**C1**
	$= GL / A$	**A1**
(b)(iv)	values have a large range	**B1**

Q13.

(b)(i)	$k = [1.29 \times (3.3 \times 10^2)^2] / 9.9 \times 10^4$	**C1**
	$= 1.4$	**A1**
(b)(ii)	percentage uncertainty = $(3 \times 2) + 4 + 2$ (= 12%) **or** fractional uncertainty = $(0.03 \times 2) + 0.04 + 0.02$ (= 0.12)	**C1**
	$\Delta k = 0.12 \times 1.42$ $= 0.17$ (*allow to 1 significant figure*)	**C1**
	$k = 1.4 \pm 0.2$	**A1**

Q14.

(a)	absolute uncertainty $= (1.6 / 100) \times 0.0125$ $= 2 \times 10^{-4}$ m	**A1**
(b)(ii)	percentage uncertainty $= 2.8 + (2 \times 1.6)$ (= 6%) **or** fractional uncertainty = $0.028 + (2 \times 0.016)$ (= 0.06)	**C1**
	absolute uncertainty $= 0.06 \times 3100$ $= 190$ N m^{-2} (*allow to 1 significant figure*)	**A1**

Q15.

(b)(i)	$T = 2\pi \times (200 \times 10^{-3} / 25)^{0.5}$ $= 0.56$ s	**A1**
(b)(ii)	percentage uncertainty = $(2\% + 8\%) / 2$ (= 5%) **or** fractional uncertainty = $(0.02+0.08) / 2$ (= 0.05)	**C1**
	$\Delta T = 0.56 \times 0.05$ $= 0.028$ (s)	**C1**
	$T = (0.56 \pm 0.03)$ s	**A1**