**1**

**(a)** **(i)** $g = \frac{4\pi^2 \times 1.50}{2.48^2}$
$= 9.63\ m\ s^{-2}$

**(ii)** $\frac{\Delta g}{g} = 0.02 + (0.03)(2)$
$= 0.08$

$\Delta g = (0.08)(9.6317)$
$= 0.77$
$\approx 0.8\ m\ s^{-2}\ (1\ sf)$

**2**

**(a)** **(i)** The ratio of mass to volume of the object or substance

**(ii)** $kg\ m^{-3}$

**(b)** unit of $v$ is $m\ s^{-1}$
$p/\rho$ has unit of $kg\ m^{-1}\ s^{-2} / \ kg\ m^{-3}$
$\sqrt{p/\rho}$ has unit of $m\ s^{-1}$
LHS = RHS. hence $\gamma$ has no unit

**3**

**(a)** $k\ = \frac{[(3)(1.29)(3.3\ \times\ 10^2)^2]}{9.9\ \times\ 10^4}$
$= 4.3$

**(b)** $\frac{\Delta k}{k} = 2 \times \frac{8}{100} + 0.07 + \frac{0.09}{1.29}$
$= 0.30$
$\Delta k = 0.30 \times 4.257$
$= 1.28$
$\approx 1\ (1\ sf)$
$k = 4 \pm 1$

**(c)** unit of $fA$ = unit of speed
unit of $A$ = $m\ s^{-1}/s^{-1}$
= $m$

**4**

**(a)** $[C] = \frac{[Q][L]}{[t][A][\Delta T]}$
$= \frac{(kg\ m^2\ s^{-2})(m)}{(s)(m^2)(K)}$
$= kg\ m\ s^{-3}\ K$

**(b)** **(i)** The evidence is seen by the shift of graph to the right of a fixed value and did not pass through the origin. If there is no systematic error, the best fit line must pass through the origin.

**(ii)** Gradient = $CA\Delta T$

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$$= \frac{56.0 - 10.0}{0.300 - 0.070}$$

$$= \frac{46.0}{0.230}$$
$$= 2.00\ W\ m$$
$$C = \frac{2.00}{\pi(0.40 \times 10^{-2})^2(100 - 0)}$$
$$= 398\ kg\ m\ s^{-3}\ k^{-1}$$

**(iii)** No, the gradient of the straight line is equal to $CA\Delta T$ and the gradient is not affected by the presence of the systematic error. Therefore the accuracy of C is not affected.

**5**

**(a)**
$$\rho = \frac{m}{abc}$$
$$= \frac{0.234}{(5.13 \times 10^{-2})(11.38 \times 10^{-2})(1.72 \times 10^{-2})}$$
$$= 2330\ kg\ m^{-3}$$

**(b)**
$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$$
$$\Delta\rho = \left(\frac{0.02}{0.234} + \frac{0.01}{5.13} + \frac{0.01}{11.38}\right)(2330)$$
$$= 40\ kg\ m^{-3}$$
$$\rho = (2330 \pm 40)\ kg\ m^{-3}$$

**(c)** Zero error of balance or vernier calliper readings.

**6**

**(a)** Systematic errors are constant deviations of the readings of a physical quantity, either consistently higher, or consistently lower, than its true value.
Random errors are deviations of readings of a physical quantity, randomly scattered about the mean reading.

**(b)** **(i)** $21.150\ cm$
$20.980\ cm$

**(ii)** $0.005\ cm$

**(iii)**
$$A = \pi\left(\frac{D}{2}\right)^2 = \frac{\pi D^2}{4}$$
$$\frac{\Delta A}{A} = \frac{2\Delta D}{D}$$
$$\Delta D = 0.005 + 0.005 = 0.01$$
$$\frac{\Delta A}{A} = \frac{2(0.01)}{21.150 - 20.980} \times 100\% = 12\%$$

**7**

**(a)** Precision is defined as a measure of how close the experimental values are to each other. Accuracy is defined as a measure of how close the experimental values are to the true value of the physical quantity.

**(b)** **(i)**

$$g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2(50.0 \times 10^{-2})}{(1.42)^2} = 9.7893\ m\ s^{-2}$$

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + \frac{2\Delta T}{T}$$

$$= \frac{0.2}{50.0} + \frac{0.02}{1.42}$$

$$\Delta g = \left(\frac{0.2}{50.0} + \frac{0.02}{1.42}\right)(9.7893)$$

$$= 0.17704$$

$$\approx 0.2\ m\ s^{-2}$$

$$g = 9.8 \pm 0.2\ m\ s^{-2}$$

**(ii)** $0.005\ cm$

**(iii)** There is error due to human reaction time. Taking a large number of oscillations will reduce the fractional/percentage uncertainty of the measurement of time. The absolute uncertainty is the same but taking more oscillations reduces the effect in the calculation of T.

**8**

**(a)**

$$T = \sqrt{4\pi^2\left(\frac{0.500}{9.8}\right)}$$

$$= 1.4192\ s$$

$$\frac{\Delta T}{T} = \frac{1}{2}\left(\frac{\Delta L}{L} + \frac{\Delta g}{g}\right)$$

$$= \frac{1}{2}\left(\frac{0.2}{50.0} + \frac{0.1}{9.8}\right)$$

$$= 0.00710$$

$$\Delta T = 0.01008\ s$$

$$\approx 0.01\ s\ (1\ sf)$$

$$T = 1.42 \pm 0.01\ s$$

**(b)** **(i)** In each reading, the uncertainty is limited by the human reaction error of about 0.2 $s$

For $\Delta T_{first} = 0.2\ s$

$$\Delta T_{second} = \frac{0.2}{20} = 0.01\ s$$

Since the estimated uncertainty of the second set of data is smaller, it will have smaller scattering and will be a more precise set of data.

**(ii)** The error is a systematic error which cannot be reduced by taking the average time.

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**9**

**(a)**

$s_y = u_y t + \frac{1}{2} a_y t^2$
$a_y = \frac{2s_y}{t^2}$
$a_y = 9.72\ m\ s^{-2}$

**(b)** The larger the data point, the smaller the percentage uncertainty since the absolute uncertainty is a constant. Hence, improving the reliability.

**(c)**

$\frac{\Delta g}{g} = \frac{\Delta s_y}{s_y} + \frac{2\Delta t}{t}$
$\Delta g = \frac{0.001}{1.75} + 2\left(\frac{0.006}{0.600}\right)(9.722)$
$= 0.2\ m\ s^{-2}$
$g = 9.7 \pm 0.2\ m\ s^{-2}$

**(d)** Plot a graph of $s_y$ against $t^2$ and a linear graph will be obtained. The gradient is $\frac{1}{2}g$. A best fit line with all the data points will reduce the random error.

**10**

The units of $P$ are $\frac{(kg\ m\ s^{-2})(m)}{s}$
The units of $k\rho A^p v^q$ are $kg\ m^{-3+2p+q} s^{-q}$
For equation to be homogeneous, the units of LHS and RHS must be the same

$s^{-3} = s^{-q}$
$q = 3$
$m^2 = m^{-3+2p+q}$
$2 = -3 + 2p + q$
$p = 1$

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