In this part you will determine the density of brass by ... the mass of a brass rod using a pan balance, and calculating its volume. The latter is given by $V = \pi (d/2)^2 L$, where L is the length of the rod and d its diameter.

For this:

1. Measure L using a vernier caliper.
2. Measure d using a micrometer.
3. Repeat each measurement five times.
4. Measure the mass of the brass rod once.

V. DATA ANALYSIS

PART 1: ESTIMATING π

1. Record your data in Table 2.1 below:

Table 2.1

D = 3.945 cm	ΔD = ± 0.0025 cm	$\frac{\Delta D}{D}$ = 0.00063
C = 12.4 cm	ΔC = ± 0.05 cm	$\frac{\Delta C}{C}$ = 0.004

2. Using the measured values of (D) and (C), calculate an estimate of π.

$\pi = \frac{C}{D} = \frac{12.4}{3.945} = 3.14$

3. Calculate the error, Δπ, in your estimate of π. Show your calculations in detail.

Remember: $\Delta\pi = \pi \cdot \sqrt{\left(\frac{\Delta D}{D}\right)^2 + \left(\frac{\Delta C}{C}\right)^2}$

$\Delta\pi = 3.14 \sqrt{\left(\frac{0.0025}{3.945}\right)^2 + \left(\frac{0.05}{12.4}\right)^2} = 0.024$

0.013

4. Compare your estimate of π with the accepted value ($\pi_{accepted}$=3.14159).

$PE = \frac{|\pi_{exp} - \pi_{accepted}|}{\pi_{accepted}} * 100\% = \frac{|3.14 - 3.14159|}{3.14159} * 100\%$

$= 0.05\%$

5. Which error contributes most to π? Explain your answer in detail.

$\frac{\Delta C}{C} = 0.004$, $\frac{\Delta D}{d} = 0.00063$

$0.004 > 0.00063$

→ D.C. ←

PART 2: DETERMINATION OF DENSITY

1. Record your measured values of L in Table 2.2 below.
2. Calculate the error, $\Delta\bar{L}$, in the average measured length and enter the result in Table 2.2.

Table 2.2

Trial No.	L_i(cm)	$(L_i - \bar{L})^2$ (cm²)	$\bar{L}$ = 7.45 cm (cm)
1	7.45	0	
2	7.44	0.0001	
3	7.48	0.0009	$\sum_{i=1}^{5}(L_i - \bar{L})^2 = 0.001$
4			
5			
$\Delta\bar{L} = \pm 0.013$ cm	$\frac{\Delta\bar{L}}{\bar{L}} = 0.0017$		

3. Record your measured values of d in Table 2.3 below.
4. Calculate the error, $\Delta\bar{d}$, in the average measured diameter and enter the result in Table 2.3.

Table 2.3

Trial No.	d_i (cm)	$(d_i - \bar{d})^2$ (cm²)	$\bar{d} = 0.496$
1	0.498	4*10^-6	$\sum_{i=1}^{5}(d_i - \bar{d})^2 = 5*10^{-6}$
2	0.496	0	
3	0.495	1*10^-6	
4			
5			
$\Delta\bar{d} = \pm$ 9.13 *10^-4 cm			$\frac{\Delta\bar{d}}{\bar{d}} = 1.84*10^{-3}$

5. Record your measured value of m in Table 2.4 below. Estimate the error Δm and calculate the ratio $\frac{\Delta m}{m}$.

Table 2.4

$m =$	12.31	g
$\Delta m =$	±0.01	g
$\frac{\Delta m}{m} =$	0.0008	

Remember: $|\Delta m|$ is the smallest division of the balance used.

6. Calculate ρ, the density of the rod, using the value of π, determined in part 1, and the measured values of $\bar{L}$, $\bar{d}$, and mass m, determined in part 2.

$\rho = \frac{4m}{d^2 \pi L} = \frac{4 * 12.31}{(0.496)^2 (3.14)(7.45)} = 8.54$ g/cm³ ....

....

....

....

7. Calculate $\Delta\rho$ using $\Delta\rho = \rho\sqrt{\left(\frac{\Delta m}{m}\right)^2 + \left(\frac{\Delta\pi}{\pi}\right)^2 + \left(\frac{2\Delta\bar{d}}{\bar{d}}\right)^2 + \left(\frac{\Delta\bar{L}}{\bar{L}}\right)^2}$.

Show the details of your calculation.

$\Delta\rho = \rho\sqrt{(0.0008)^2 + \left(\frac{0.024}{3.14}\right)^2 + (2 \times 1.84 \times 10^{-3})^2 + (0.0017)^2}$

$= 0.019\,\rho$ 0.07

8. Order the errors $\frac{\Delta\pi}{\pi}$, $\frac{\Delta\bar{d}}{\bar{d}}$, $\frac{\Delta\bar{L}}{\bar{L}}$, and $\frac{\Delta m}{m}$ according to their contribution to the error in ρ.

$\frac{\Delta\pi}{\pi} = 0.0076$ / $\frac{2\Delta d}{d} = 0.00368$ / $\frac{\Delta L}{L} = 0.0017$ / $\frac{\Delta m}{m} = 0.0008$

$0.0076 (\pi) > 0.00368 (d) > (0.0017 (L) > 0.0008 (m)$

9. The accepted value of ρ is: $\rho_{accepted} = 8.3\ g/cm^3$. Your measured value is in the range $[\bar{\rho}-\Delta\bar{\rho}, \bar{\rho}+\Delta\bar{\rho}]$. Is $\rho_{accepted}$ within the range?

$\bar{\rho} - \Delta\bar{\rho} = (8.54 - 0.019) = 8.521$
$\bar{\rho} + \Delta\bar{\rho} = (8.54 + 0.019) = 8.559$ ⇒ NO

10. Justify your answer in step 9.

experiment error

11. State and discuss three sources of error in this experiment.

1) errors in the reporting of results.
2) calculation errors.
3) the equipment is disabled (Vernier caliper, micrometer)