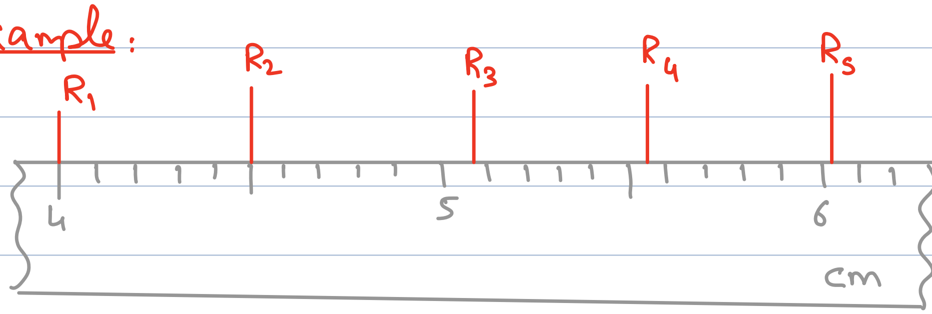
Representation of a value along with absolute error:-

Notation:

Symbol of Physical Qty = Value in same no. of d.p as in absolute error ± Absolute error in 1 s.f.

Example:



$R_1 = 4.0 \pm 0.1\,cm$

$R_2 = 4.5 \pm 0.1\,cm$

$R_3 = 5.1 \pm 0.1\,cm$

$R_4 = 5.6 \pm 0.1\,cm$

$R_5 = 6.0 \pm 0.1\,cm$

Mathematical errors:-

(a) Fractional error :-

Formula:

$$\text{Fractional error} = \frac{\text{Absolute error}}{\text{Value}} = \frac{\Delta R}{R}$$

Example:

If $L = 21.4 \pm 0.1\,cm$

$$\frac{\Delta L}{L} = \frac{0.1}{21.4} = 4.67 \times 10^{-3}$$

(b) Percentage error :-

Formula:

$$\text{Percentage error} = \left(\frac{\text{Absolute error}}{\text{Value}}\right) 100 = \frac{\Delta R}{R} \times 100$$

Example:

If $L = 21.4 \pm 0.1\,cm$

$$\text{Percentage error in Length} = \frac{0.1}{21.4} \times 100 = 0.467\,\%$$

(c) Arithmetic errors:-

1- Addition:

Formula:

$$\text{Addition} = \left(\text{Sum of values}\right) \pm \left(\text{Sum of Absolute errors}\right)$$

Example:

$L_1 = 12.4 \pm 0.1\,cm$

$L_2 = 36.2 \pm 0.1\,cm$

$L = L_1 + L_2 = ?$

$L = (L_1 + L_2) \pm (\Delta L_1 + \Delta L_2)$

$L = (12.4 + 36.2) \pm (0.1 + 0.1)$

$= 48.6 \pm 0.2\,cm$

multiple reading and then add up increases error and reduces accuracy.

2- Subtraction:-

Formula:

$$\text{Subtraction} = \left(\text{Difference of values}\right) \pm \left(\text{Sum of Absolute errors}\right)$$

Example:

$L_1 = 12.4 \pm 0.1\ cm$

$L_2 = 36.2 \pm 0.1\ cm$

$L = L_2 - L_1 = ?$

$L = (L_2 - L_1) \pm (\Delta L_2 + \Delta L_1)$

$L = (36.2 - 12.4) \pm (0.1 + 0.1)$

$= 23.8 \pm 0.2\ cm$

3- Multiplication:

Formula

$$\text{Multiplication} = \begin{pmatrix}\text{Product}\\ \text{of values}\end{pmatrix} \pm \begin{pmatrix}\text{Sum of fractional}\\ \text{error of all}\\ \text{quantities}\end{pmatrix}\begin{pmatrix}\text{Product}\\ \text{of values}\end{pmatrix}$$

Example: If $V = 12.8 \pm 0.2V$

$I = 4.3 \pm 0.1A$

$P = VI = ?$ along with its Absolute error.

Sol:

$$P = VI \pm \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right)(VI)$$

$$P = (12.8)(4.3) \pm \left(\frac{0.2}{12.8} + \frac{0.1}{4.3}\right)\left[(12.8)(4.3)\right]$$

$P = 55.04 \pm 2.14\ W$

Since Absolute error must be in 1 S.f and value must have same no. of decimal places as in Absolute error.

$P = 55 \pm 2\ W$

4- Division :

Formula

Division $= \left(\text{Ratio of values}\right) \pm \left(\text{Sum of fractional error of all quantities}\right)\left(\text{Division of values}\right)$

Example: If $V = 12.8 \pm 0.2V$

$I = 4.3 \pm 0.1A$

$R = \frac{V}{I} = ?$ along with its Absolute error.

Sol:

$$R = \frac{V}{I} \pm \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right)\left(\frac{V}{I}\right)$$

$$R = \frac{12.8}{4.3} \pm \left(\frac{0.2}{12.8} + \frac{0.1}{4.3}\right)\left(\frac{12.8}{4.3}\right)$$

$$R = 2.98 \pm 0.11$$

Since Absolute error must be in 1 s.f

$$R = 3.0 \pm 0.1\,\Omega$$

(d) Power rule errors:-

1- If $a = x^m$

Fractional error in $a = \frac{\Delta a}{a} = m\left(\frac{\Delta x}{x}\right)$

i.e Fractional error in power quantity

$= \text{Power}\left(\text{Fractional error of base quantity}\right)$

Example:

If Length of a Cube is

$L = 2.8 \pm 0.2\,cm$

Calculate

(i) Value of volume

$$V = L^3 = (2.8)^3 = 21.952$$
$$= 22.0\,cm^3$$

(ii) Fractional error in volume

$$\frac{\Delta V}{V} = 3\left(\frac{\Delta L}{L}\right) = 3\left(\frac{0.2}{2.8}\right) = 0.214$$

(iii) Absolute error in volume

$$\frac{\Delta V}{V} = 0.214 \Rightarrow \Delta V = (0.214)(V) \Rightarrow \Delta V = (0.214)(21.95)$$
$$\Delta V = 4.697 \Rightarrow \Delta V = 4.7\,cm^3$$

(b) State value of volume along with its absolute error.

$$V = 22 \pm 5\ cm^3$$

2- If $a = x^m y^n$

Fractional error in $a = \frac{\Delta a}{a} = m\left(\frac{\Delta x}{x}\right) + n\left(\frac{\Delta y}{y}\right)$

i.e Fractional error in power quantity

= Power (Fractional error of 1st base quantity) + Power (Fractional error of 2nd base quantity)

Example:

If $I = 2.6 \pm 0.2\,A$

$R = 12.8 \pm 0.4\,\Omega$

(a) Calculate

(i) Fractional error in Power $(P = I^2 R)$

$$\frac{\Delta P}{P} = 2\left(\frac{\Delta I}{I}\right) + 1\left(\frac{\Delta R}{R}\right)$$

$$= 2\left(\frac{0.2}{2.6}\right) + \left(\frac{0.4}{12.8}\right)$$

$$= 0.185$$

(ii) Value of Power

$$P = I^2 R = (2.6)^2 (12.8)$$

$$P = 86.5$$

(iii) Absolute error in Power

$$\frac{\Delta P}{P} = 0.185 \Rightarrow \frac{\Delta P}{86.5} = 0.185$$

$$\Delta P = 16.0\,W$$

(b) Write value of Power along with its absolute error.

Absolute error must be in 1 s.f

$$P = 87 \pm 20\,W$$

3 - If $a = x^m / y^n$

Fractional error in $a = \frac{\Delta a}{a} = m\left(\frac{\Delta x}{x}\right) + n\left(\frac{\Delta y}{y}\right)$

i.e Fractional error in power quantity

= Power (Fractional error of 1st base quantity) + Power (Fractional error of 2nd base quantity)

Example:

If $V = 12.6 \pm 0.2\,V$

$R = 2.8 \pm 0.4\,\Omega$

(a) Calculate

(i) Fractional error in Power $\left(P = \frac{V^2}{R}\right)$

$$\frac{\Delta P}{P} = 2\left(\frac{\Delta V}{V}\right) + 1\left(\frac{\Delta R}{R}\right)$$

$$= 2\left(\frac{0.2}{12.6}\right) + \left(\frac{0.4}{2.8}\right)$$

$$= 0.158$$

(ii) Power dissipated (Lost) in the resistor

$$P = \frac{V^2}{R} = \frac{(12.6)^2}{2.8} = 56.7\,W$$

(iii) Absolute error in Power

$$\frac{\Delta P}{P} = 0.158 \Rightarrow \frac{\Delta P}{56.7} = 0.158$$

$$\Delta P = 8.96\,W$$

(b) State the value of Power along with its absolute error.

$$P = 57 \pm 9 \ W$$

March-20/11/Q5

A micrometer is used to measure the diameters of two cylinders.

$d_1 =$ diameter of first cylinder = (12.78 ± 0.02) mm

$d_2 =$ diameter of second cylinder = (16.24 ± 0.03) mm

The difference in the diameters is calculated.

What is the uncertainty in this difference?

A 0.01 mm **B** 0.02 mm **C** 0.03 mm **D** 0.05 mm

$$d = d_2 - d_1$$
$$d = (d_2 - d_1) \pm (\Delta d_2 + \Delta d_1)$$
$$d = (16.24 - 12.78) \pm (0.03 + 0.02)$$
$$d = 3.46 \pm 0.05 \text{ mm}$$

	γ	X	UV	V	IR	MW	RW
f	10^{20}	10^{18}	10^{16}	10^{14}	10^{12}	10^{10}	10^{8}

March 20/22

1 (a) Length, mass and temperature are all SI base quantities.

State **two** other SI base quantities.

1. Time | 4- Luminous Intensity

2. Electric current

3- Amount of a substance

[2]

(b) The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

$l = 1.50\,\text{m} \pm 2\%$ → $\frac{\Delta l}{l} \times 100 = 2\%$

and $T = 2.48\,\text{s} \pm 3\%$. → $\frac{\Delta T}{T} \times 100 = 3\%$

(i) Calculate the acceleration of free fall g.

$$g = \frac{4(3.14)^2(1.50)}{(2.48)^2} = 9.6185$$

g = 9.62 $\text{m}\,\text{s}^{-2}$ [1]

(ii) Determine the percentage uncertainty in g.

$$\frac{\Delta g}{g} \times 100 = \frac{\Delta l}{l} \times 100 + 2\left(\frac{\Delta T}{T}\right)100$$

$$= 2\% + 2(3\%)$$

$$= 8\%$$

percentage uncertainty = 8 % [2]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the absolute uncertainty of the calculated value of g.

$$\frac{\Delta g}{g} \times 100 = 8 \Rightarrow \frac{\Delta g}{g} = \frac{8}{100} \Rightarrow \Delta g = \left(\frac{8}{100}\right)g$$

$$\Delta g = \left(\frac{8}{100}\right)(9.62) = 0.7694$$

absolute uncertainty = ... $\text{m}\,\text{s}^{-2}$ [1]

Absolute error must be true in 1sf

$\Delta g = 0.8$

[Total: 6]

Nov. 20/23/ Q1

(a) An electromagnetic wave has a wavelength of 85 µm.

(i) State the wavelength, in m, of the wave.

85×10^{-6} m

wavelength = 8.5×10^{-5} m [1]

(ii) Calculate the frequency, in THz, of the wave.

$v = f\lambda$

$3.00 \times 10^{8} = f(8.5 \times 10^{-5})$

$f = 3.529 \times 10^{12}$

frequency = 3.53 THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

Infrared [1]

(b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

The manufacturer of the coil states that the value of L, in SI base units, is $7.5 \times 10^{-6} \pm 5\%$.
The current I in the coil is measured as (0.50 ± 0.02) A.

$\frac{\Delta L}{L} \times 100 = 5\%$

The values of L and I are used to calculate E.

Determine the percentage uncertainty in the value of E.

$$\left(\frac{\Delta E}{E}\right)100 = 2\left(\frac{\Delta I}{I}\right)100 + \left(\frac{\Delta L}{L}\right)100$$

$$= 2\left(\frac{0.02}{0.50}\right)100 + 5\%$$

$$= 2(4\%) + 5\%$$

$$= 13\%$$

percentage uncertainty = ... % [2]

[Total: 6]

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ERRORS AND UNCERTAINTIES (Page 1)

1. When asked to determine the resistance R of a given conductor from 6 sets of voltage V and current I readings, student **A** plotted V against I and obtained the gradient of the plot while student **B** found R by averaging 6 sets of (V, I) readings. Which of the following statements is **correct**?

(A) Procedure taken by student **A** will only reduce random errors computed for R.
(B) Procedure taken by student **B** will only reduce the systematic errors in finding R.
(C) Procedure taken by student **A** reduces both systematic and random errors.
(D) Procedure taken by student **B** is basically the same in effect as taken by student A.

2. Which of the following experimental techniques reduces the systematic error of the quantity being investigated?
(A) timing a large number of oscillations to find a period Random error↓
(B) measuring several antinodal distances on a standing wave to find the mean internodal distance. Random error↓
(C) measuring the diameter of a wire repeatedly and calculating the average. Random error↓
(D) Adjusting an ammeter to remove its zero error before measuring a current.

3. When comparing *systematic* and *random* errors, the following pairs of properties of errors in an experimental measurement may be considered:
P_1 : error can possibly be eliminated Systematic
P_2 : error cannot possibly be eliminated Random
Q_1 : error is of constant sign and magnitude Systematic
Q_2 : error is of varying sign and magnitude Random
R_1 : error will be reduced by averaging repeated measurements Random
R_2 : error will not be reduced by averaging repeated measurements. Systematic
Which properties apply to **random** errors?
(A) P_1 , Q_1 , R_2 **(B)** P_1 , Q_2 , R_2
(C) P_2 , Q_2 , R_1 **(D)** P_2 , Q_1 , R_1

4. Which experimental technique reduces the systematic error of the quantity being investigated?
(A) adjusting an ammeter to remove its zero error before measuring a current
(B) measuring several internodal distances on a standing wave to find the mean internodal distance Random ↓
(C) measuring the diameter of a wire repeatedly and calculating the average Random ↓
(D) timing a large number of oscillations to find a period Random ↓

5. A micrometer screw gauge is used to measure the diameter of a copper wire. The reading with the wire in position is shown in diagram 1. The wire is removed and the jaws of the micrometer are closed. The new reading is shown in diagram 2

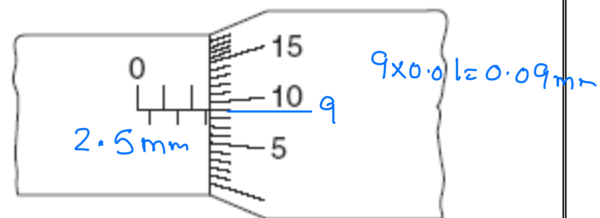


Diagram 1

2.5+0.09=2.59mm

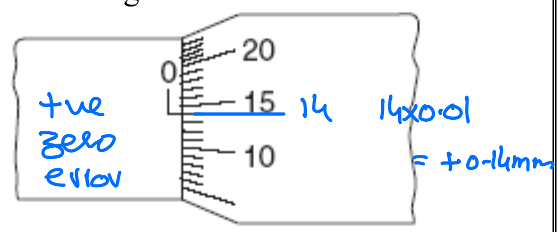


Diagram 2

2.59 − 0.14 = 2.45mm

What is the diameter of the wire?
(A) 1.90mm **(B)** 2.45mm
(C) 2.59mm **(D)** 2.73mm

6. Which of the following recorded measurements of a physical quantity has the greatest percentage uncertainty?
(A) (243 ± 1) g **(B)** (76.4 ± 0.2) mm
(C) (22.43 ± 0.01) s **(D)** (36.4 ± 0.5) mA

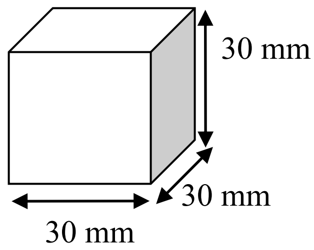
7. The resistance of an unknown resistor can be found by formula $\boldsymbol{R=V/I}$.
The voltmeter reading has a 3 % uncertainty and the ammeter has a 2% uncertainty.
What is the uncertainty in the calculated resistance?
(A) 1.5% **(B)** 5 % **(C)** 3% **(D)** 6%

8. A thermometer can be read to an accuracy of ± 0.5 °C. This thermometer is used to measure a temperature rise from 40 °C to 100 °C.
What is the percentage uncertainty in the measurement of temperature rise?
(A) 0.5% **(B)** 0.8% **(C)** 1.3% **(D)** 1.7%

9. In an experiment, the length and breadth of a rectangular card was found to be (64 ± 2) mm and (47 ± 1) mm respectively.
The uncertainty in the **area is at most**
(A) 75 mm^2 **(B)** 150 mm^2
(C) 100 mm^2 **(D)** 200 mm^2

10. An experiment is done to measure the resistance of a wire.
The current in the wire is 1.0 ± 0.2 A and the potential difference across the wire is 8.0 ± 0.4 V.
What is the resistance of the wire and its uncertainty?
(A) (8.0 ± 0.2) Ω
(B) (8.0 ± 0.6) Ω
(C) (8 ± 1) Ω
(D) (8 ± 2) Ω

11. The dimensions of a cube are measured with vernier calipers.



The measured length of each side is 30 mm. If the vernier calipers can be read with an uncertainty of ± 0.1 mm, what does this give for the approximate uncertainty in the value of its volume?

(A) 1/27 % **(B)** 0.3 % **(C)** 1/3 % **(D)** 1%

12. The diameter, height and mass of a given cylinder are found to be (3.6 ± 0.1) cm, (2.8 ± 0.1) cm and (56 ± 1)g respectively. The density of the cylinder can be quoted as

(A) (1.97 ± 0.22) g cm^{-3}
(B) (1.9 ± 0.2) g cm^{-3}
(C) (2.00 ± 0.22) g cm^{-3}
(D) (2.0 ± 0.2) g cm^{-3}

13. In an experiment, a radio-controlled car takes 2.50 ± 0.05 s to travel 40.0 ± 0.1 m.
What is the car's average speed and the uncertainty in this value?

(A) 16 ± 1 m s^{-1} **(B)** 16.0 ± 0.2 m s^{-1}
(C) 16.0 ± 0.4 m s^{-1} **(D)** 16.00 ± 0.36 m s^{-1}

14. In a simple electrical circuit, the current in a resistor is measured as (2.50 ± 0.05) mA. The resistor is marked as having a value of 4.7 Ω ± 2%.
If these values were used to calculate the power dissipated in the resistor, what would be the percentage uncertainty in the value obtained?

(A) 2 % **(B)** 4 % **(C)** 6 % **(D)** 8 %

15. A student makes measurements from which she calculates the speed of sound as 327.66 ms^{-1}.She estimates that her result is accurate to ±3 %.
Which of the following gives her result expressed to the appropriate number of significant figures?

(A) 327.7 ms^{-1} **(B)** 328 ms^{-1}
(C) 330 ms^{-1} **(D)** 300 ms^{-1}

16. The power loss P in a resistor is calculated Using the formula

$$P = V^2/R.$$

The uncertainty in the potential difference V is 3% and the uncertainty in the resistances R is 2%. What is the uncertainty in P?

(A) 4% **(B)** 7% **(C)** 8% **(D)** 11%

17. The following are the readings of a travelling microscope when the cross-wires are aligned at opposite ends of a diameter of a capillary bore.

R_1 = (21.14 ± 0.01) cm
R_2 = (20.98 ± 0.01) cm

What is the maximum percentage uncertainty in the area of the cross-section of the capillary bore?

(A) 13 % **(B)** 25 %
(C) 18 % **(D)** 29 %

18. Using a micrometer, the diameter of apiece of wire was found to be (0.15 ± 0.01) mm. The area of cross-section of the wire may be quoted as

(A) 0.01767 ± 0.00236 mm^2
(B) 0.0176714 ± 0.002356 mm^2
(C) (1.76 ± 0.24) x 10^{-2} mm^2
(D) (0.018 ± 0.002) mm^2

19. The wall thickness of a cylindrical glass tube is determined by measuring its external and internal diameters with the help of vernier calipers. If the readings obtained are (27.23 ± 0.01) cm and (24.15 ± 0.01) cm respectively, the wall thickness of the glass tubing is

(A) 3.08 ± 0.02 cm **(B)** 1.54 ± 0.02 cm
(C) 3.08 ± 0.01 cm **(D)** 1.54 ± 0.01 cm

20. A student finds the density of liquid by measuring its mass and its volume. The following is a summary of his measurements.

Mass of empty beaker = (20 ± 1) g
Mass of empty beaker + liquid = (70 ± 1) g
Volume of liquid =(10.0 ± 0.6) cm^3

He correctly calculates the density of the liquid as 5.0 g cm^{-3}.
What is the uncertainty in this value?

(A) 0.3 g cm^{-3} **(B)** 0.5 g cm^{-3}
(C) 0.6 g cm^{-3} **(D)** 2.6 g cm^{-3}

21. A student uses a metre rule to measure the length of an elastic band before and after stretching it. The lengths are recorded as

band before stretching, L_o = 50.0 ± 0.1 cm
band after stretching, L_s = 51.6 ± 0.1 cm.

Determine

(a) the change in length (L_s - L_o), quoting your answer with its uncertainty,

(L_s - L_o) = ………………… cm **[1]**

(b) the fractional change in length, $\frac{(L_s - L_o)}{L_o}$

fractional change = ……………… **[1]**

(c) the uncertainty in your answer in **(b)**.

uncertainty = ………………….. **[3]**

SALT ACADEMY

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MEASUREMENTS & ERRORS

1 One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically.

The diameter d of the wire and the load F are measured as

$d = 0.40 \pm 0.02$ mm,
$F = 25.0 \pm 0.5$ N.

(a) For the measurement of the diameter of the wire, state

(i) the name of a suitable measuring instrument,

Micrometer Screw Gauge [1]

(ii) how random errors may be reduced when using the instrument in **(i)**.

Measure several diameters along the length of wire using Ratchet and get their mean value/ diameter. [2]

(b) The stress σ in the wire is calculated by using the expression

$$\sigma = \frac{4F}{\pi d^2}.$$

$d = 0.40 \pm 0.02$ mm,
$F = 25.0 \pm 0.5$ N.

(i) Show that the value of σ is $1.99 \times 10^8\,\text{N m}^{-2}$.

$$\sigma = \frac{4(25.0)}{(3.14)(0.40 \times 10^{-3})^2}$$

$$= 1.99 \times 10^8\ \text{Nm}^{-2}$$

[1]

(ii) Determine the percentage uncertainty in σ.

$$\frac{\Delta\sigma}{\sigma} \times 100 = \frac{\Delta F}{F} \times 100 + 2\left(\frac{\Delta d}{d}\right)100$$

$$= \left(\frac{0.5}{25.0}\right)100 + 2\left(\frac{0.02}{0.40}\right)100$$

$$= \underline{12}\ \%$$

percentage uncertainty = ...% [2]

(iii) Use the information in **(b)(i)** and your answer in **(b)(ii)** to determine the value of σ, with its absolute uncertainty, to an appropriate number of significant figures.

$$\frac{\Delta\sigma}{\sigma} = \frac{7}{100} \Rightarrow \Delta\sigma = \left(\frac{12}{100}\right)(1.99\times10^{8})$$

$$\Delta\sigma = 2.4\times10^{7}$$

But Absolute error must be in 1 s.f, $\Delta\sigma = 0.2\times10^{8}$

$\sigma = 1.99\times10^{8} \pm 0.2\times10^{8}$

Now value must have same no. of d.p as in Absolute error

σ = (2.0 ± 0.2) 10^{8} N m^{-2} [2]

[Total: 8]

{Q. 1/Nov. 17/9702/22}

2. A double-slit interference experiment is used to determine the wavelength of light from a monochromatic source.

$$x = \frac{\lambda D}{a} \Rightarrow \lambda = \frac{xa}{D}$$

The following measurements are used.

slit separation $a = 0.50 \pm 0.02\,\text{mm}$

fringe separation $x = 1.7 \pm 0.1\,\text{mm}$

distance between slits and screen $D = 2.000 \pm 0.002\,\text{m}$

$$\left(\frac{\Delta\lambda}{\lambda}\right)100 = \left(\frac{\Delta x}{x}\right)100 + \left(\frac{\Delta a}{a}\right)100 + \left(\frac{\Delta D}{D}\right)100$$

$$= \left(\frac{0.1}{1.7}\right)100 + \left(\frac{0.02}{0.50}\right)100 + \left(\frac{0.002}{2.000}\right)100$$

What is the percentage uncertainty in the calculated wavelength?

A 0.1% **B** 1% **C** 6% **D** 10%

{Q. 5/Nov. 17/9702/11}

3. A school has a piece of aluminium that it uses for radioactivity experiments. Its thickness is marked as 3.2 mm. A student decides to check this value. He has vernier calipers which give measurements to 0.1 mm and a micrometer which gives measurements to 0.01 mm.

Not done yet

Which statement **must** be correct?

A The micrometer gives a more accurate measurement.

B The micrometer gives a more precise measurement.

C The vernier calipers give a more accurate measurement.

D The vernier calipers give a more precise measurement.

{Q. 4/Nov. 17/9702/23}

4. Four possible sources of error in a series of measurements are listed.

1 an analogue meter whose scale is read from different angles — Parallax error — Random

2 a meter which always measures 5% too high — systematic

3 a meter with a needle that is not frictionless, so the needle sometimes sticks slightly — Random error

4 a meter with a zero error — systematic

Which errors are random and which are systematic?

	random error	systematic error
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	3 and 4	1 and 2

{Q. 5/Nov. 17/9702/13}

*A-grade

1 The volume V of liquid flowing in time t through a pipe of radius r is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8 C l}$$

where P is the pressure difference between the ends of the pipe of length l, and C depends on the frictional effects of the liquid.

An experiment is performed to determine C. The measurements made are shown in Fig. 1.1.

$\frac{V}{t}$ / $10^{-6}\,m^3 s^{-1}$	P / $10^3\,N m^{-2}$	r / mm	l / m
1.20 ± 0.01	2.50 ± 0.05	0.75 ± 0.01	0.250 ± 0.001

Fig. 1.1

(a) Calculate the value of C.

$$C = \frac{\pi P r^4}{8\left(\frac{V}{t}\right) l}$$

$$C = \frac{(3.14)(2.50\times10^{3})(0.75\times10^{-3})^4}{8(1.20\times10^{-6})(0.250)}$$

$$= 1.04\times10^{-3}$$

C = ... $N s m^{-2}$ [2]

(b) Calculate the uncertainty in C. $\Delta C = ?$

$$\frac{\Delta C}{C} = \frac{\Delta P}{P} + 4\left(\frac{\Delta r}{r}\right) + \frac{\Delta\left(\frac{V}{t}\right)}{\frac{V}{t}} + \frac{\Delta l}{l}$$

$$\frac{\Delta C}{1.04\times10^{-3}} = \frac{0.05}{2.50} + 4\left(\frac{0.01}{0.75}\right) + \frac{0.01}{1.20} + \frac{0.001}{0.250}$$

$\Delta C = 0.089\times10^{-3}$ uncertainty = $\pm 0.089\times10^{-3}$ $N s m^{-2}$ [3]

(c) State the value of C and its uncertainty to the appropriate number of significant figures.

Uncertainty in C in 1 sf, $\Delta C = \pm 0.09\times10^{-3}$
Value must be in 2 dp as ΔC is in 2 dp

C = $(1.04$ ± $0.09)\,10^{-3}$ $N s m^{-2}$ [1]