Phy 11 02 04 Accuracy and precision of measuring instruments

COMBINATION OF ERRORS

Sum or Difference

$$A = A \pm \Delta A$$

$$B = B \pm \Delta B$$

$$Z = A + B$$; find error in Z given ΔA, ΔB

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$$Z \pm \Delta Z = (A \pm \Delta A) + (B \pm \Delta B)$$

$$= \cancel{AB}\,(A + B) \pm (\Delta A) \pm (\Delta B)$$

$$\Delta Z = \Delta A + \Delta B$$

Subtraction $Z = A - B$

$$Z \pm \Delta Z = (A \pm \Delta A) - (B \pm \Delta B)$$

$$= (A - B) \pm \Delta A \pm \Delta B$$

7:37 / 55:25

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$\pm \Delta A \pm \Delta B$

$\rightarrow$ maximum error

$\Delta A + \Delta B$

$Z = A - B$

$\Delta Z = \Delta A + \Delta B$

8:16 / 55:25

Product or Quotient

$$Z = \frac{A}{B} \quad \text{or} \quad A \times B$$

$$Z = AB$$

$$Z \pm \Delta Z = (A \pm \Delta A)(B \pm \Delta B)$$

$$Z \pm \Delta Z = (AB) \pm \Delta A\,B \pm \Delta B\,A \pm \Delta A \Delta$$

Divide by Z

$$1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta A}{A} \pm \frac{\Delta B}{B} \pm \frac{\Delta A \, \Delta B}{AB}$$

a) $\pm \rightarrow +$

b) $(\Delta A \, \Delta B) \rightarrow$ neglect

product of 2 small quanti

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

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$$Z = \frac{A}{B}$$

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

$$Z = \frac{A^n}{B^m}$$

$$\frac{\Delta Z}{Z} = \pm\left(n\frac{\Delta A}{A} + m\frac{\Delta B}{B}\right)$$

12:50 / 55:25

$$Z = \frac{A}{B}$$

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

$$Z = \frac{A^n}{B^m}$$

$$\frac{\Delta Z}{Z} = \pm \left(n\frac{\Delta A}{A} + m\frac{\Delta B}{B} \right)$$

% error in Z = n (% error in A) + m (% error in B)

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$$H = I^2 R t$$

I is current
R is resistance
t is time
$H \rightarrow$ Heat generate

Error in measurements of I, R and t are 2%, 3% and 1%
Find relative error in measurement of H?

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$$H = I^2 R t$$

I is current
R is resistance
t is time
H → Heat generated

Error in measurements of I, R and t are 2%, 3% and 1%.
Find relative error in measurement of H?

$$\frac{\Delta H}{H} = 2\frac{\Delta I}{I} + \frac{\Delta R}{R} + \frac{\Delta t}{t}$$

15:43 / 55:25

$$\frac{\Delta H}{H} \times 100\% = 2\frac{\Delta I}{I} \times 100\% + \frac{\Delta R}{R} \times 100\% + \frac{\Delta t}{t} \times 100\%$$

$$= 2 \times 2\% + 3\% + 1\%$$

$$= 8\%$$

error in ΔH (in %) $= \pm 8\%$.

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Significant figures

whenever any measurement is reported the uncertainity in the measurement is in the last digit.

Time period = 1.62 s

1 & 6 are reliable digits

2 → uncertainty

18:50 / 55:25

Significant figures

Whenever any measurement is reported the uncertainity in the measurement is in the last digit.

Time period = 1.62 s

1 & 6 are reliable digits

2 → uncertainty

1.62 s → Correct with 3 significant d...

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1.62 → 3 significant digits

287.5 cm   4 significant digits

Significant digits indicate the precision of an instrument which depend on the least count.

Choice of different units should not affect the number of significant digits.

2.308 cm → 4 significant digits

23.08 mm

0.02308 m

Rules

1) All non zero digits are significant
2) Zeros between 2 non zero digits are signifcant irrespective of decimal point.

3) If number is less than 1

0. _ _ _ _ _ .

Zeros to the right of decimal point but to the left of 1^{st} non zero digit are not significant.

0.00238   3 significant

0

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4) If full number (no decimal point) trailing zeros are not significant

123 m ← 3 significant digits

12300 cm

↓ not be counted in significant digits

25:47 / 55:25

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5) If number with decimal point

e.g. 3.500 ← # of sig. digits = 4

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5) If number with decimal point

e.g. 3.500 ← # of sig. digits = 4

Report the number in scientific notation powers of 10

27:10 / 55:25

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number expressed as

$a \times 10^{b}$ ← expoment
+ve or -ve

a is between 1 and 10

ORDE

number expressed as

$a \times 10^{b}$ ← exponent +ve or −ve

$\underset{\sim}{a}$ is between 1 and 10

ORDER OF MAGNITUDE

express scientific notation

$a \times 10^{b}$ if $1 \leq a \leq 5$

order of magnitude $= 10^{b}$

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ORDER OF MAGNITUDE

$a \times 10^{b}$ if $1 \leq a \leq 5$

round it off to 1

$\approx 10^{b}$

b is called order of magnitude.

$5 \leq a \leq 10 \rightarrow$ round of to the next digit

$10^{(b+1)} \longrightarrow (b+1)$ is called the order of magnitude

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31:03 / 55:25

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1.28×10^{7} m

order of mag ~ 10^{7} m

Diameter of Hydrogen atom

1.06×10^{-10} m

order of magnitude ~ 10^{-10} m

32:03 / 55:25

Formulas

constants

for eg. Diameter = 2 × radius

↑ exact

∞ significant

Rules for operations

Final result cannot be more accurate than the original measured values.

e.g. $\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{4.237 \text{ gms}}{2.51 \text{ cm}^3}$

$\text{density} = 1.68804780876 \ \frac{g}{cm^3}$

Multiplication or Division

Final result should retain as many significant figures as are there in original number with least significant digits.

$m = 4.237 g$ ← 4

$V = 2.51 cm^3$ ← 3

density → 3 sig. digits

Final result should retain as many significant figures as are there in original number with least significant digits.

$m = 4.2379$ ← 4

$V = 2.51\ cm^3$ ← 3

density → 3 sig. digits

$= 1.69\ gm/cm^3$

② Addition or Subtraction

Final result retain as many decimal places as are there in the number with least decimal places.

$$\begin{array}{r} 436.32\ g \\ 227.2\ g \\ 0.301\ g \\ \hline 663.821\ g \end{array}$$

663.8 g

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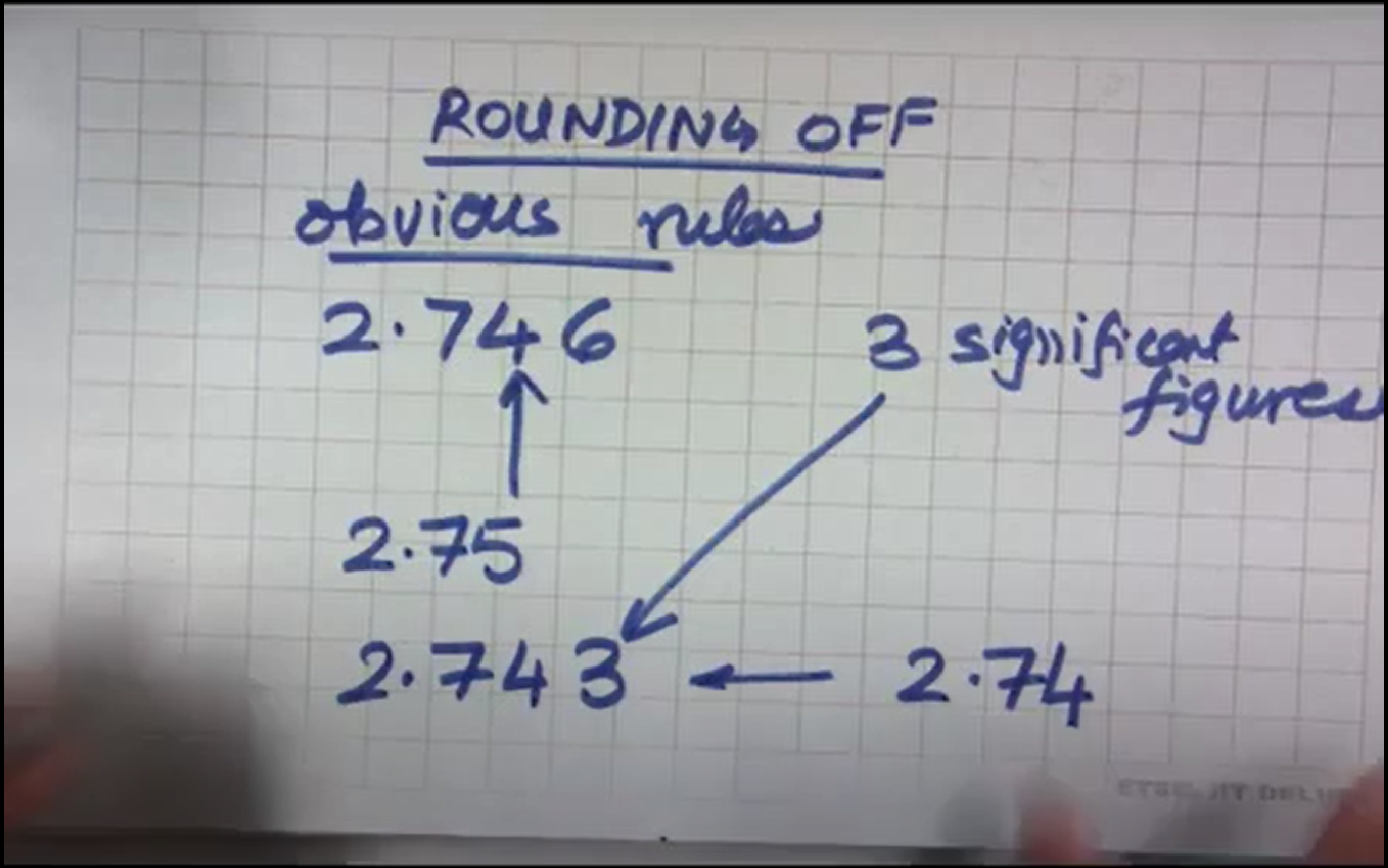

42:56 / 55:25

If

Preceding digit is raised by 1
if the digit to be dropped is
bigger than 5
left unchanged if the digit to
be dropped is less than 5.

2.745 ← 3 sig. digits

If the digit to be dropped is 5, then if the preceding digit is even, drop 5. → 2.74

If the preceding digit is odd, add 1.

e.g. 2.735 → 2.74

2.7351 up to 3 significant digits

↓

2.74

51

2.7451 ← 3 significant digits

2.75

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$L = 16.2\ cm$

$B = 10.1\ cm$

Area

$163.62\ cm^2$

$L = 16.2 \pm 0.1\ cm$

$B = 10.1 \pm 0.1\ cm$

$A = (16.2 \pm 0.1)(10.1 \pm 0.1)\ cm^2$

48:48 / 55:25

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$$L = 16.2 \pm 0.1 \text{ cm}$$

$$\Delta L = 0.1 \text{ cm}$$

$$\frac{\Delta L}{L} = \frac{0.1}{16.2} \times 100\% = 0.6\%$$

$$\frac{\Delta B}{B} = \frac{0.1}{10.1} \times 100\% = 1\%$$

$$A = LB \; ; \; \frac{\Delta A}{A} = \frac{\Delta L}{L} + \frac{\Delta B}{B}$$

49:58 / 55:25

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$$\left(\frac{\Delta A}{A}\right)\% = 0.6\% + 1\%$$
$$= 1.6\%$$

$$\Delta A = \frac{1.6}{100} \times A$$

$$A = 16.2 \times 10.1$$

$$A = 163.62\ cm^2 \pm 1.6\%$$

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50:51 / 55:25

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$$\left(\frac{\Delta A}{A}\right)\% = 0.6\% + 1\%$$
$$= 1.6\%$$

$$\Delta A = \frac{1.6}{100} \times A$$

$$A = 16.2 \times 10.1$$

$$A = 163.62\ cm^2 \pm 1.6\%$$
$$= 164\ cm^2$$

51:25 / 55:25

$$\left(\frac{\Delta A}{A}\right)\% = 0.6\% + 1\%$$

$$= 1.6\%$$

$$\Delta A = \frac{1.6}{100} \times A$$

$$A = 16.2 \times 10.1$$

$$A = 163.62\ cm^2 \pm 1.6\% \leftarrow 2.6\ cm^2$$

$$= 164\ cm^2 \pm 3\ cm^2$$

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Relative error:

depends not only on the number of significant digits but also on the number.

$$1.029 \pm 0.01 g$$

$$\text{rel. error} = \frac{0.01}{1.02}$$

53:22 / 55:25

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$$9.89\,g \pm 0.01\,g$$

$$\text{relative error} = \frac{0.01}{9.89} \times 100\,\%$$

$$= 0.1\,\%$$

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$9.89\,g \pm 0.01\,g$

relative error $= \frac{0.01}{9.89} \times 100\,\%$

$= 0.1\,\%$

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multiple step calculations

intermediate steps we retain 1 extra digit

54:48 / 55:25