Oxford Cambridge and RSA

Monday 17 January 2022 – Morning

Level 3 Cambridge Technical in Applied Science

05848/05849/05874 Unit 3: Scientific analysis and reporting

Time allowed: 2 hours
C342/2201

You must have:
- a ruler (cm/mm)

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink.

Centre number

Candidate number

First name(s)

Last name

Date of birth D D M M Y Y Y Y

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- The Periodic Table is on the back page.
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

FOR EXAMINER USE ONLY	
Question No	Mark
1	/9
2	/15
3	/19
4	/14
5	/12
6	/15
7	/16
Total	**/100**

Answer **all** the questions.

1 The title page of a publication in a science journal is shown in **Fig. 1.1**.

The contents are fictional.

Laboratory Technology Reports

Volume 11, September 2016, Pages 11 – 32

An evaluation of different chromatography techniques: manual and automated.

Friedrich B. Bauer [a], Burkhard A. Fischer [a], Lucia C. Garcia [b], Pablo González [b], Jurgen D. Koch [a], Paula R. López [b], Ella A. Neumann [a], Hans R. Schmidt [a], Frieda W. Weber [a], Amelia T. Wolff [a]

[a] Scientific Gymnasium of Technology, Germany

[b] Instituto de Investigaciones Tecnologicas, Spain

Received 11 January 2016, Revised 20 February 2016, Accepted 10 April 2016, Available online 12 April 2016.

Fig. 1.1

(a) State the name of the journal that this work was published in.

.... **[1]**

(b) **(i)** State the year that this scientific investigation was published.

.... **[1]**

(ii) Determine the approximate number of months between the paper submission date and when it was finally accepted for publication.

.... **[1]**

(c) Explain how you can tell that this work was a collaboration between two research groups.

....

.... **[1]**

(d) State the name of the country where most of the authors worked.

.... **[1]**

(e) One advantage of an online publication is that the findings can be made available to the wider scientific community very quickly.

Explain how **Fig. 1.1** shows that this is true.

.... **[1]**

(f) This article was published in a peer-reviewed journal.

(i) Describe what 'peer review' means.

....

....

....

.... **[2]**

(ii) State why peer review is important.

.... **[1]**

2 Amari is a student who is interested in astronomy.

He finds the infographic in **Fig. 2.1** displayed in a science museum.

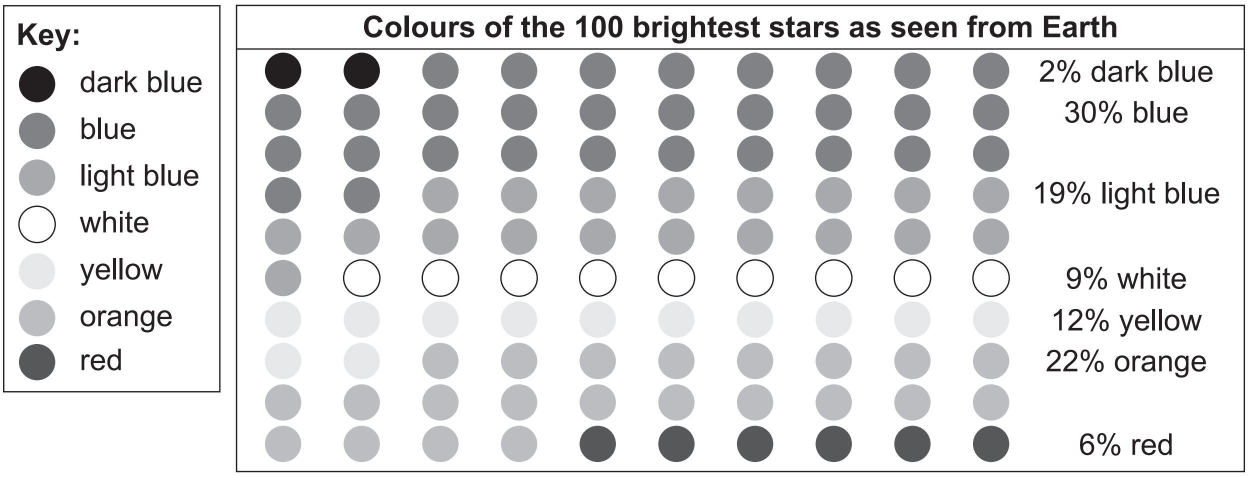

Fig. 2.1

(a) On **Fig. 2.2**, draw and label a bar chart of the percentage data shown in **Fig. 2.1**, in the order of colour shown.

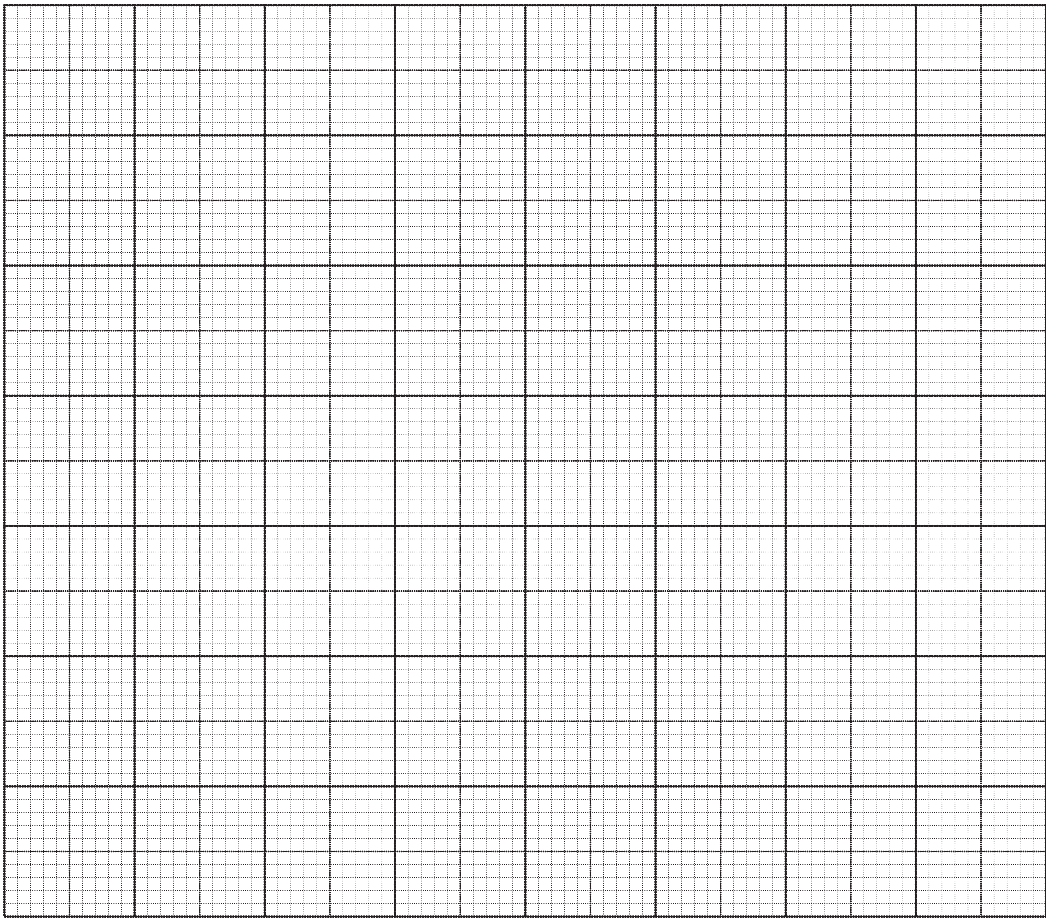

Fig. 2.2

[3]

(b) Amari finds some more information about stars and their colours.

Fig. 2.3 shows the range of wavelengths produced by three different stars:

- a G-type star with a temperature of 5000 °C
- a K-type star with a temperature of 4000 °C
- a M-type star with a temperature of 3000 °C.

The peak of each curve is the wavelength at which each type of star emits most of its light.

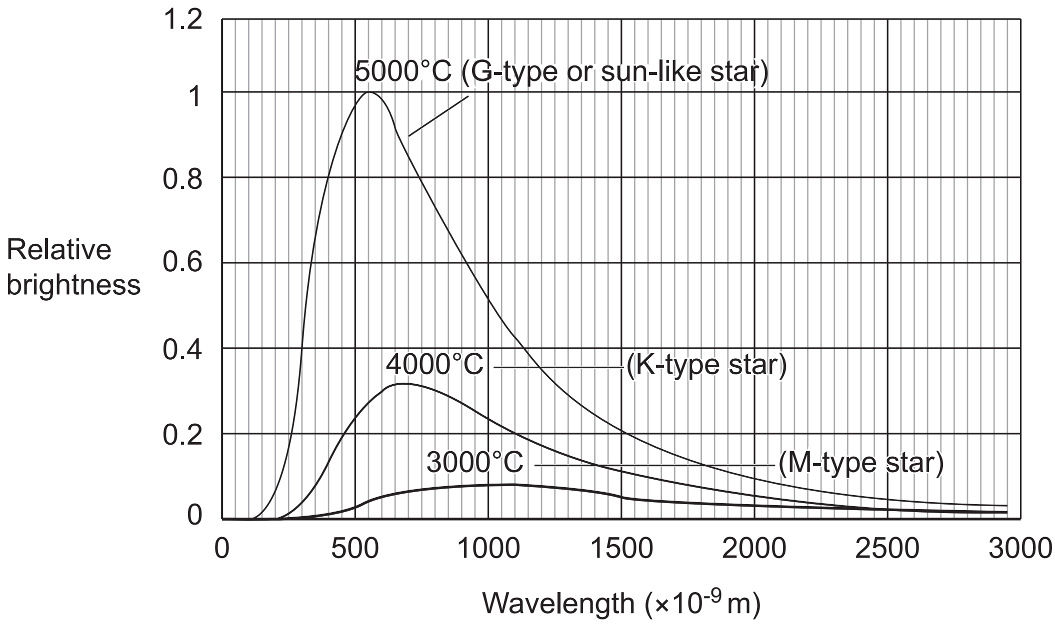

Fig. 2.3

Table 2.1 shows the range of wavelengths for the colours of the visible part of the electromagnetic spectrum.

Colour	**Wavelength range (m)**
red	(635 to 700) × 10^{-9}
orange	(590 to 635) × 10^{-9}
yellow	(560 to 590) × 10^{-9}
green	(520 to 560) × 10^{-9}
cyan	(490 to 520) × 10^{-9}
blue	(450 to 490) × 10^{-9}

Table 2.1

(i) Draw two vertical lines on **Fig. 2.3** to indicate the range of wavelengths of the visible part of the electromagnetic spectrum.

[1]

(ii) Amari thinks it is possible to deduce the average colour of the stars in **Fig. 2.3**.

Which **two** statements are reasons why Amari **cannot** deduce the average colour of these stars?

Tick (✓) **two** boxes.

A single colour is a range of wavelengths.	☐
Colour is discontinuous but wavelength is continuous.	☐
Colour is continuous but wavelength is discontinuous.	☐
Stars emit a range of wavelengths.	☐
The wavelength ranges are irregular.	☐

[2]

(iii) Determine the wavelength and colour of the maximum relative brightness of the G-type star in **Fig. 2.3**.

Wavelength = ... $\times 10^{-9}$ m

Colour = ...

[2]

(iv) Suggest why the G-type star appears to be white.

....

.... **[1]**

(c) (i) Amari thinks that red stars are cooler than blue stars.

Explain why Amari is correct.

Use information from **Fig. 2.3** and **Table 2.1** to support your answer.

....

....

....

.... **[2]**

(ii) Amari then concludes that most of the stars near Earth are hotter than the sun.

Suggest why Amari could be correct, and suggest why he could also be incorrect.

Use information from **Fig. 2.1** and **Fig. 2.3** to support your answers.

Reason Amari could be correct

....

....

....

....

Reason Amari could be incorrect

....

....

....

....

[4]

3 Layla measures the e.m.f. of seven AAA batteries.

She connects each battery across the terminals of a digital multi-meter and records the e.m.f.

Her results are shown in **Table 3.1**.

Battery	e.m.f. (V)
1	1.60
2	1.48
3	1.57
4	1.60
5	1.60
6	1.44
7	1.58

Table 3.1

(a) Using the data in **Table 3.1**:

(i) Find out the mode and median of the e.m.f. values.

Mode = ... V

Median = ... V
[2]

(ii) Calculate the mean e.m.f.

Give your answer to **3** significant figures.

Mean = ... V **[3]**

(b) Calculate the variance, s^2, and standard deviation, s, of the e.m.f values.

Use the equation:

$(n - 1) \times s^2 = \Sigma (X_i - \overline{X})^2$

- n = number of samples
- X_i = e.m.f. of each individual cell
- $\overline{X}$ = mean e.m.f. calculated in **(a)(ii)**.

s^2 = ...

s = ...

[6]

(c) Layla measures the e.m.f. of the batteries again, in millivolts, mV.

Her new results are shown in **Table 3.2**.

Battery	e.m.f. (mV)
1	1614
2	1618
3	1516
4	1618
5	1591
6	1619
7	1619

Table 3.2

Layla concludes that:
'there are two batteries in **Table 3.1** whose e.m.f values are due to measurement error'.

(i) Identify the two batteries.

Battery number .... and battery number ....

[1]

(ii) Explain your answer to **(c)(i)**. Use ideas about precision in your answer.

....

....

.... **[2]**

(d) Draw lines to connect each experimental analysis term with its correct definition.

Experimental analysis term	**Definition**
Accuracy	The closeness of agreement between measured values obtained by repeated measurements.
Measurement error	Error due to measurements varying in an unpredictable way.
Precision	Error due to measurements differing from the true value by a consistent amount.
Random error	The closeness of the instrument reading to the true value.
Systematic error	The difference between a measured value and the true value.

[5]

4 Felix is investigating changes in the rate of flow of water.

Fig. 4.1 is a diagram of the apparatus he uses.

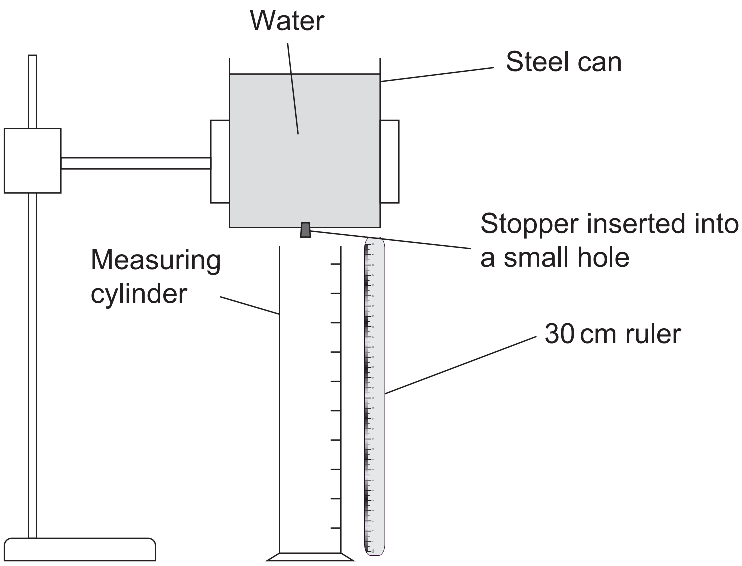

Fig. 4.1

- Felix removes the stopper from the steel can and starts a stopwatch.
- Felix records the time taken for the water level inside the measuring cylinder to reach a height of 2.0 cm, 4.0 cm and so on up to 14.0 cm.

(a) The time, t_1, when the water level reaches a height, h_1, of 12.0 cm is 251 s.

The time, t_2, when the water level reaches a height, h_2, of 14.0 cm is 330 s.

The diameter, d, of the measuring cylinder is 7.1 cm.

(i) Calculate the change in height, Δh, and the time taken, Δt, for the change in height.

$\Delta h = (h_2 - h_1) =$ .... cm

$\Delta t = (t_2 - t_1) =$ .... s

[1]

(ii) Calculate the average rate of flow, R, of the water as the water level increases from h_1 to h_2.

Give the units of R.

Use your values of Δh and Δt from **(a)(i)** in the equation:

$$R = \frac{\pi d^2 \Delta h}{4 \Delta t}$$

R = ... units .... **[3]**

(iii) Felix plots two graphs as shown in **Fig. 4.2**.

The graphs show:

- the time taken against height of water in the measuring cylinder (marked with triangles ▲)
- the rate of flow of water, R, against height of water in the measuring cylinder (marked with crosses ×)

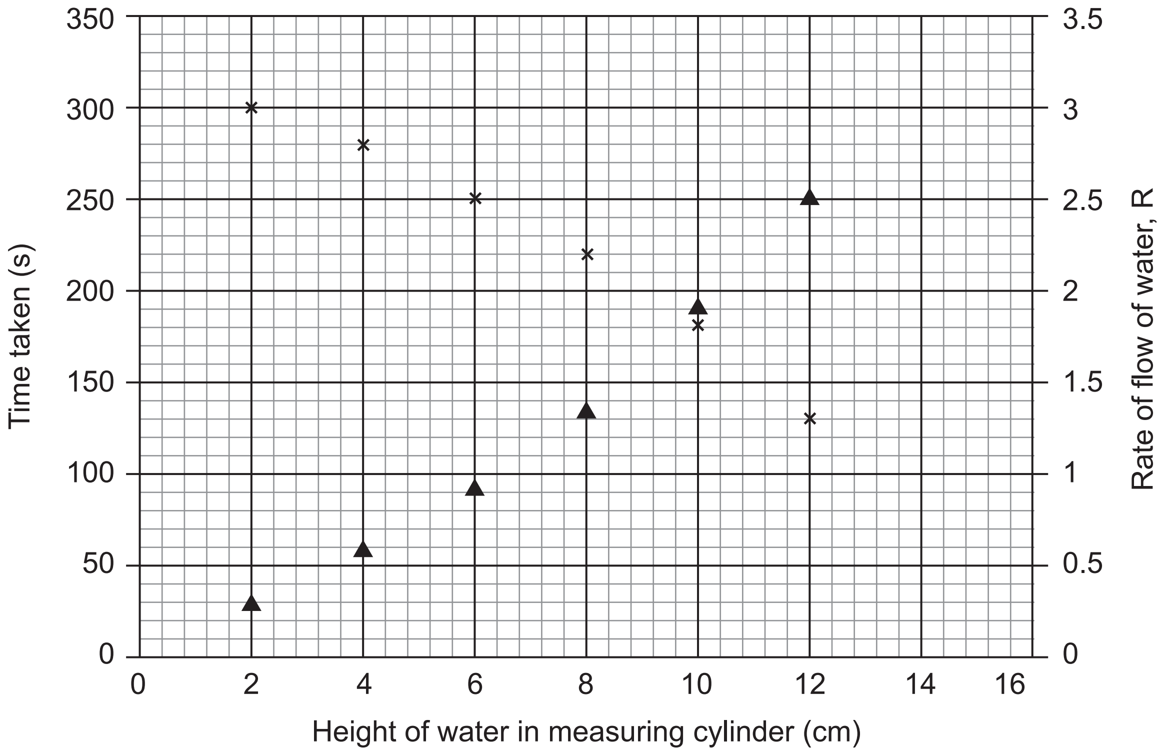

Fig. 4.2

On the grid in **Fig. 4.2**:

- draw the symbol ▲ to plot the value of t_2 used for the calculation in **(a)(i)**.
- draw the symbol **×** to plot your value of R calculated in **(a)(ii)**.

[2]

(iv) Use **Fig. 4.2** to estimate R when the height of the water in the measuring cylinder is 1.0 cm.

R = ... **[1]**

(b) Felix takes a photograph of the water in the measuring cylinder as it reaches the 14 cm mark on the ruler.

The photograph is shown in **Fig. 4.3**.

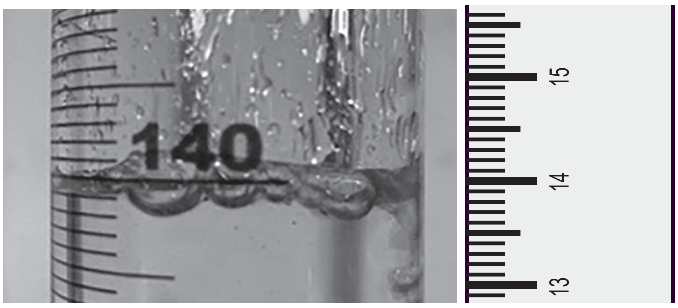

Fig. 4.3

Describe and explain the trend in R, and suggest why there are errors in Felix's time measurement at 14 cm.

Use information from **Fig. 4.2** and **Fig. 4.3** to support your answer.

....

....

....

....

....

....

....

....

....

....

....

.... **[6]**

(c) Felix concludes that the rate of flow of water, R, depends on the depth of water in the steel can.

Which equation can be used to increase confidence in Felix's conclusion?

Tick (✓) **one** box.

Acceleration = change in speed ÷ time ☐

Density = mass ÷ volume ☐

Force = mass × acceleration ☐

Pressure = density × gravitational field strength × depth ☐

[1]

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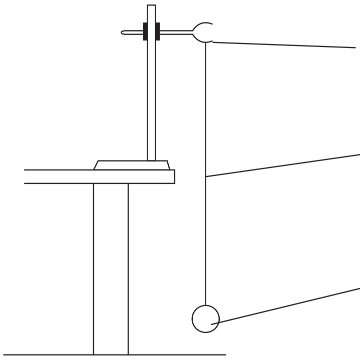
5 Amos is investigating a simple pendulum. He sets up the apparatus shown in the diagram.



A pendulum string is tied to a clamp at one end and has a heavy weight known as a pendulum bob at the other.

- Amos moves the pendulum bob from the vertical position to 12 cm to the right.
- When he releases the pendulum bob, it swings to the left and then swings back. The size of the swing (amplitude) decreases slightly with each swing.
- Amos starts a stopwatch when the pendulum is 12 cm to the right of the vertical position.
- When the distance of the pendulum bob from the vertical position decreases to 10 cm, he records the time taken.
- He continues to record the time taken each time this distance decreases by 2 cm.
- He carries out two experiments using two different lengths of pendulum string.

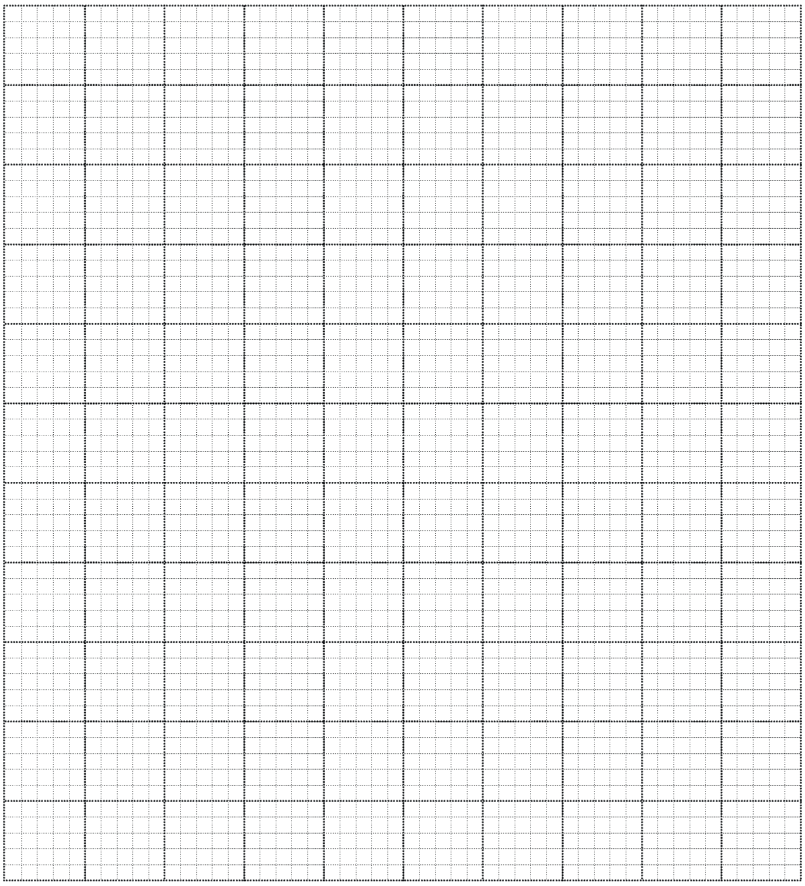
The results of his investigation are shown in the table.

Decrease in distance of pendulum bob from vertical position (cm)	0	2.0	4.0	6.0	8.0	10.0
First experiment: length of pendulum string = 130 cm:						
Time (s)	0	60	200	230	330	480
Second experiment: length of pendulum string = 54 cm:						
Time (s)	0	30	70	120	170	220

(a) Plot a graph of time (s) on the vertical axis against decrease in distance of pendulum bob from vertical postion (cm), for both sets of results from the table.

Draw curves of best fit for both sets of results **and** label the lines '130 cm pendulum' and '54 cm pendulum'.

Put a ring around the outlier on your graph.



[7]

(b) Amos estimates that the percentage uncertainty in his time measurements is ±10%.

(i) Calculate the minimum and maximum possible times when the decrease in distance is 6.0 cm, using the 130 cm pendulum string.

Minimum time = ... s

Maximum time = ... s

[2]

(ii) Draw a range bar on the graph to indicate the values calculated in **(b)(i)**.

[1]

(iii) Which **two** changes will cause the percentage **uncertainty** in the time measurements to **increase**?

Tick (✓) **two** boxes.

A larger decrease in the distance from the vertical position with each swing. ☐

A smaller decrease in the distance from the vertical position with each swing. ☐

The pendulum bob changing direction more quickly. ☐

The pendulum bob changing direction more slowly. ☐

An increase in the time for one swing of the pendulum bob. ☐

[2]

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6 Potamogeton is a type of aquatic plant, commonly known as pondweed.

Many species have leaves that float on the surface of the water and leaves that are underwater.

Some species are entirely submerged, and all of their leaves and stems are underwater.

The features of one species of Potamogeton are shown in **Fig. 6.1**.

Fig. 6.1

The table shows some features of Potamogeton.

The table is used to identify individual species.

Species	**Underwater leaf width (mm)**	**Underwater leaf tip shape**	**Underwater leaf blade shape**	**Floating leaf tip shape**
P. biculpatus	0.1 – 0.4	acute	linear	lanceolate
P. spirillus	0.5 – 2	obtuse	linear	obtuse
P. robbinsii	3 – 8	acute	linear	n/a
P. crispus	3 – 8	rounded	linear	n/a
P. gramineus	3 – 27	acuminate	elliptic	acuminate
P. perfoliatus	7 – 40	acute	lanceolate	n/a
P. nodosus	10 – 35	acute	lanceolate	obtuse
P. amplifolius	15 – 58	acuminate	lanceolate	obtuse
P. pulcher	60 – 165	acute	lanceolate	acute

n/a = the species does not have any floating leaves, all leaves are submerged.

(a) A partly completed classification key of the information in the table is shown in **Fig. 6.2**.

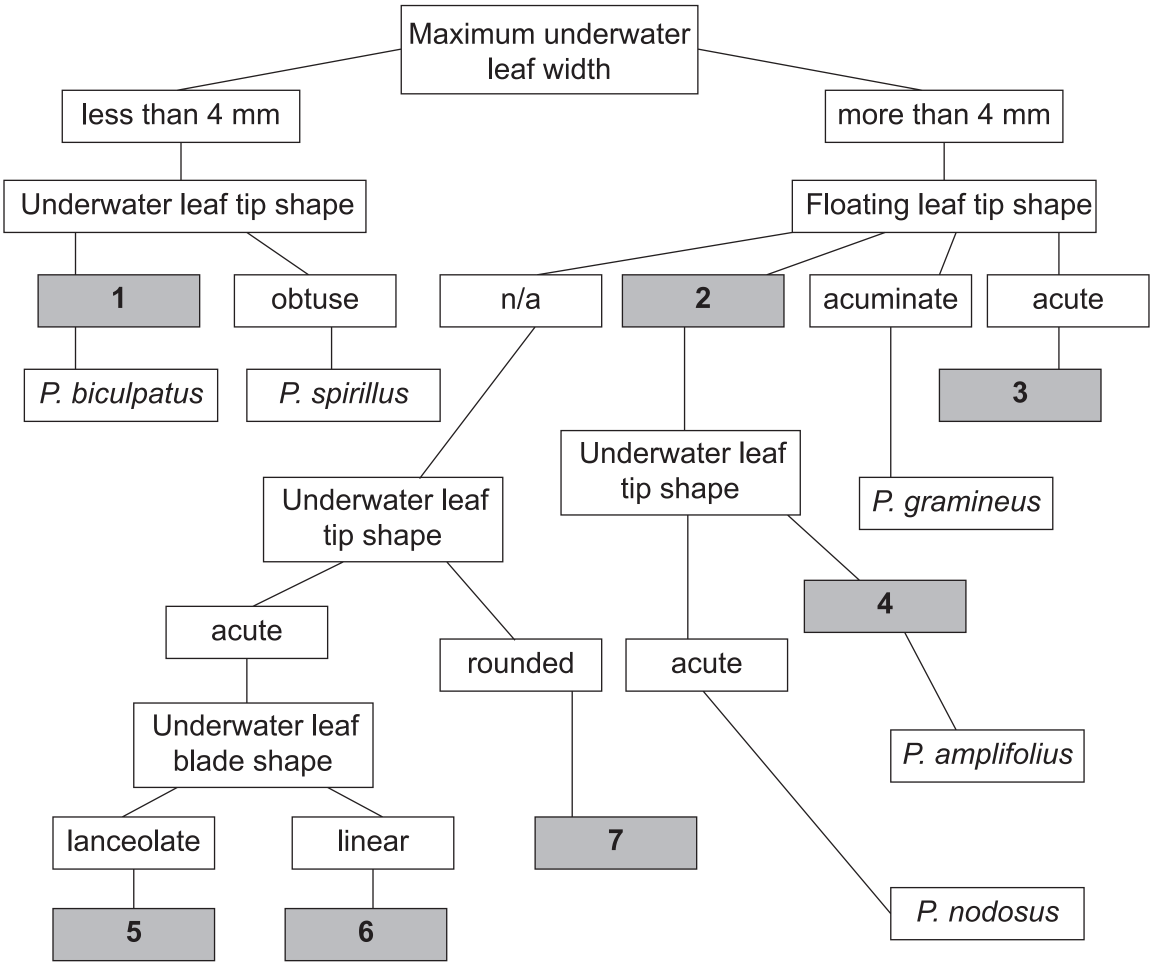

Fig. 6.2

Complete the classification key in **Fig. 6.2** by writing the correct word next to each number in the list.

Use the table.

1 ....

2 ....

3 ....

4 ....

5 ....

6 ....

7 ....

[7]

(b) **(i)** Explain why it is difficult to distinguish between *P. nodosus* and *P. amplifolius*.

....

....

....

.... **[2]**

(ii) Suggest **one** feature, other than those described in **Table 6.1**, which can be used to identify different plants.

.... **[1]**

(c) Complete the sentences about Potamogeton.

Use the words.

You can use each word once, more than once, or not at all.

binomial	**family**	**genus**	**monomial**
numerical	**phylum**	**polynomial**	

Potamogeton is the name of a plant ....

The naming system used to identify all plants, including for example *P. crispus*

is ....

[2]

(d) Environmental scientists often study the presence of pondweeds in freshwater.

Pondweeds are indicator species.

Explain why the ability to distinguish between different species of pondweed is important for assessing the quality of the environment.

....

....

....

....

....

.... **[3]**

7 An acid-base titration is one technique that chemical laboratories can use to determine the concentration of a substance.

Other titration techniques can be used to determine the concentration of substances that are not acids or bases.

(a) Complete the table by identifying **two** alternative titration techniques.

Tick (✓) **two** boxes.

Complex formation	
Density	
Optometry	
Redox	
Spectroscopy	

[2]

(b) Ivan is a technician working in a scientific analysis laboratory.

He determines the concentration of chloride ions (Cl^-) in seawater by titration against silver nitrate, using potassium chromate as the indicator.

- When silver nitrate is added from the burette to the sample of seawater, Ivan observes a white precipitate.
- When sufficient silver nitrate has been added to react with all the chloride ions in the seawater, additional silver nitrate reacts with the potassium chromate indicator forming a coloured precipitate. This is the end point of the titration.

(i) State the name of the precipitate formed at the end point.

.... **[1]**

(ii) State the colour of the precipitate at the end point.

.... **[1]**

(c) Potassium chromate is a carcinogen.

State **one** precaution that Ivan should take when working with potassium chromate.

.... **[1]**

(d) Silver nitrate solutions can cause chemical burns.

State what action Ivan should immediately take if silver nitrate gets onto his skin.

.... **[1]**

(e) Ivan dissolves 2.125 g of silver nitrate solid, $AgNO_3$, in distilled water. He then transfers the solution to a 250 cm^3 volumetric flask and makes up to the 250 cm^3 mark with more distilled water.

(i) Calculate the molar mass of silver nitrate and use it to calculate the number of moles of silver nitrate present in the 250 cm^3 volumetric flask.

Use the equation: number of moles = $\dfrac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{)}}$

Molar mass of $AgNO_3$ = ... g mol^{-1}

Number of moles of $AgNO_3$ = ... moles

[2]

(ii) Calculate the concentration, in mol dm^{-3}, of the silver nitrate solution.

Use the equation: concentration (mol dm^{-3}) = $\dfrac{\text{number of moles}}{\text{volume (dm}^3\text{)}}$

Concentration = ... mol dm^{-3} **[1]**

(f) The normal concentration of chloride ions (Cl^-) in tap water in a coastal village is $0.01\,mol\,dm^{-3}$.

After a severe storm there is concern that the village tap water might be contaminated with sea water.

Ivan has been asked to investigate whether the tap water is contaminated.

- He uses a pipette to measure out $20.0\,cm^3$ of the tap water and adds distilled water to make a final volume of $100.0\,cm^3$.
- He titrates $25.0\,cm^3$ of the diluted tap water against a $0.100\,mol\,dm^{-3}$ standard solution of silver nitrate, using potassium chromate as the indicator.
- He finds that the average volume of $0.100\,mol\,dm^{-3}$ silver nitrate needed to reach the end point is $15.5\,cm^3$.

(i) Calculate the number of moles of Ag^+ ions in $15.5\,cm^3$ of silver nitrate.

Use the equation: $\text{number of moles} = \dfrac{\text{volume (cm}^3) \times \text{concentration (mol dm}^{-3})}{1000}$

Number of moles of Ag^+ ions = ... mol **[1]**

(ii) The equation for the reaction between silver ions (Ag^+) and chloride ions (Cl^-) is

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

Deduce the number of moles of chloride (Cl^-) ions in the $25.0\,cm^3$ of diluted tap water.

Number of moles of Cl^- ions = ... mol **[1]**

(iii) Calculate the concentration of chloride (Cl^-) ions in the **diluted** tap water.

Use the equation: $\text{concentration (mol dm}^{-3}) = \dfrac{\text{number of moles}}{\text{volume (dm}^3)}$

Concentration = ... $mol\,dm^{-3}$ **[1]**

(iv) Calculate the concentration of chloride (Cl^-) ions in the **undiluted** tap water.

Concentration = ... $mol\,dm^{-3}$ **[1]**

(v) State if the tap water tested by Ivan was contaminated with sea water.

Explain your answer.

....

.... **[1]**

(g) Ivan's job also involves finding the concentration of calcium ions in water samples taken from the local area.

Complete the sentences about the determination of calcium ions by titration.

Use the terms.

You can use each term once, more than once, or not at all.

potassium dichromate	**starch**	**EDTA**	**sodium thiosulfate**
eriochrome black T	**iodine**	**methyl orange**	

Ivan measures out 25.0 cm^3 of a sample of water and places it in a conical flask with a few drops of .... as the indicator.

He fills up the burette with a standard solution of .... and adds it to the solution in the flask until the indicator changes colour.

[2]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown in the margins – for example, 1(f)(i) or 4(b).

The Periodic Table of the Elements

Key
atomic number
Symbol
name
relative atomic mass

(1)	(2)											(3)	(4)	(5)	(6)	(7)	(0)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1 **H** hydrogen 1.0																	2 **He** helium 4.0
3 **Li** lithium 6.9	4 **Be** beryllium 9.0											5 **B** boron 10.8	6 **C** carbon 12.0	7 **N** nitrogen 14.0	8 **O** oxygen 16.0	9 **F** fluorine 19.0	10 **Ne** neon 20.2
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3											13 **Al** aluminium 27.0	14 **Si** silicon 28.1	15 **P** phosphorus 31.0	16 **S** sulfur 32.1	17 **Cl** chlorine 35.5	18 **Ar** argon 39.9
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	23 **V** vanadium 50.9	24 **Cr** chromium 52.0	25 **Mn** manganese 54.9	26 **Fe** iron 55.8	27 **Co** cobalt 58.9	28 **Ni** nickel 58.7	29 **Cu** copper 63.5	30 **Zn** zinc 65.4	31 **Ga** gallium 69.7	32 **Ge** germanium 72.6	33 **As** arsenic 74.9	34 **Se** selenium 79.0	35 **Br** bromine 79.9	36 **Kr** krypton 83.8
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	41 **Nb** niobium 92.9	42 **Mo** molybdenum 95.9	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89–103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium 144.9	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.2	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium	92 **U** uranium 238.1	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium