Measurement Tutorial Solutions

<table>
<tr><td></td><td><u>Tutorial Questions</u></td><td></td><td>SIOs / Notes</td></tr>
<tr><td>Q1</td><td>Ans: A</td><td>1</td><td>Students need to recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol).</td></tr>
<tr><td>Q2</td><td>Ans: B

Since Pressure = Force / area
Therefore,

[Pressure] = [Force] / [Area]
= [mass] [acceleration] / [Area]
= (kg) ($m\ s^{-2}$) / m^2
= $kg\ m^{-1}\ s^{-2}$</td><td>1</td><td>Students need to express derived units as products or quotients of the base units.</td></tr>
<tr><td>Q3</td><td>Ans: B

Converting all to the SI units and their scientific notations:

<table>
<tr><td></td><td></td><td>Area in m^2</td></tr>
<tr><td>A</td><td>$1 \times 10^{-2} \times 1 \times 10^{-1}$</td><td>$1 \times 10^{-3}$</td></tr>
<tr><td>B</td><td>$1 \times 10^{3} \times 1 \times 10^{-3}$</td><td>1</td></tr>
<tr><td>C</td><td>$1 \times 10^{6} \times 1 \times 10^{-9}$</td><td>$1 \times 10^{-3}$</td></tr>
<tr><td>D</td><td>$1 \times 10^{-12} \times 1 \times 10^{-6}$</td><td>$1 \times 10^{-18}$</td></tr>
</table>
</td><td>1</td><td>Students need to use the prefixes and their symbols.</td></tr>
<tr><td>Q4</td><td>Ans: C

Recall the four rules:
(i) Only terms with the same units can be added or subtracted. => Q and RS have same units
(ii) Units on both sides of an equation must be the same. => P, Q and RS have the same units
(iii) The exponent of a term has no units. E.g. In e^x, x has no units. => not applicable here
(iv) The logarithm of a quantity has no units. => not applicable here

Hence, option A is wrong.
There is no basis for us to know if option B is correct.
While option D is a correct statement, it does not relate to a homogeneous equation which is referred to in the question.
Hence the best answer is option C.</td><td>1</td><td>Students need to use SI base units to check homogeneity of physical equations.</td></tr>
</table>

<table>
<tr><td>Q5
(a)

(b)

(c)</td><td>No. of moles of iron atoms, $n = \frac{\text{mass}}{\text{molar mass}}$
$= \frac{50.4 \times 10^{-2}}{5.6 \times 10^{-2}} = 9.0\ \text{mol}$

The mass of an individual iron atom can be obtained by dividing its molar mass by the Avogadro's number.

Therefore, mass of 1 atom $= \frac{\text{mass of 1 mole of iron atoms}}{\text{Avogadro's number}}$

$= \frac{56 \times 10^{-3}}{6.02 \times 10^{23}}$

$= 9.30 \times 10^{-26}$ kg

The number of iron atoms in the cube = $n \times N_A$
$= (9.0) \times (6.02 \times 10^{23})$
$= 5.42 \times 10^{24}$</td><td></td><td></td></tr>
<tr><td>Q6</td><td>Ans: C

$[C] = \text{J K}^{-1}$
$[\alpha] = [C]/[T]$
$= \text{J K}^{-1}/\text{K}$
$= \text{J K}^{-2}$
$[\beta] = [C]/[T]^3$
$= \text{J K}^{-1}/\text{K}^3$
$= \text{J K}^{-4}$</td><td>1</td><td>Students need to express derived units as products or quotients of the base units.</td></tr>
<tr><td>Q7</td><td>Assume:
- Average heart rate of a person = 70 per minute → heart beat = 1.2 beat per sec
- Average lifespan of a person = 80 years

Estimated number of a human heart beats in a life time:
No. of times = 1.2 x (60 x 60 x 24 x365 x 80) ≈ 3×10^9</td><td>1

1</td><td>Students to note that estimates can be kept as 1 s.f.</td></tr>
<tr><td>Q8</td><td><table>
<tr><td>a.</td><td>Joe is 180 cm tall.</td><td>reasonable</td></tr>
<tr><td>b.</td><td>I rode my bike to campus at a speed of 50 m s^{-1}.</td><td>Not reasonable (50 m s^{-1} = 180 km/hr, average bike speed is abt 15.5 km/hr)</td></tr>
<tr><td>c.</td><td>I can throw a ball a distance of 2 km.</td><td>Not reasonable (if a ball is throw at a speed of 60 km/hr, it can</td></tr>
</table></td><td></td><td>Students need to make reasonable estimates of physical quantities included within the syllabus.</td></tr>
</table>

			travel to around 15 m)		
	d.	Joan's newborn baby has a mass of 33 kg.	Not reasonable (a new born is about 3.3 kg)		
	e.	I can throw a ball at a speed of 50 km/hr.	Reasonable		
	f.	The atmospheric pressure is 100 Pa.	Not reasonable (atm pressure is 10^5 Pa)		
	g.	The power of a LED light bulb is 200 W.	Not reasonable (abt 2W to 5W)		

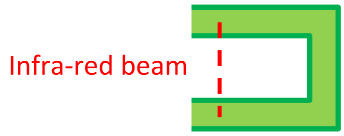
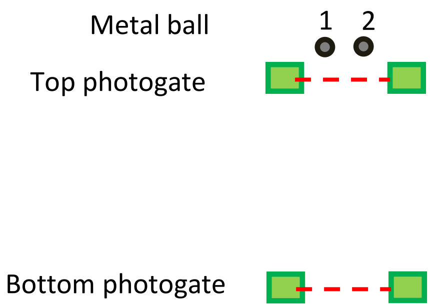
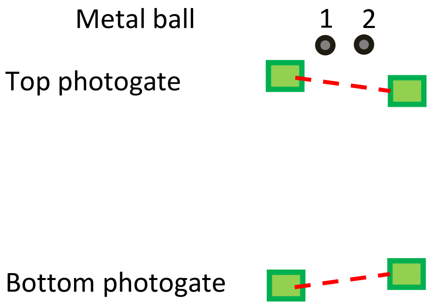
Q9	**Ans: C** Absolute uncertainty = 1% x 3.924 = 0.03924 = 0.04 V (Limit to 1 sf) Voltmeter reading should have the same precision as the absolute uncertainty. In this case, 2 d.p. Voltmeter reading with its uncertainty = (3.92±0.04) V	1	Students need to know how to calculate absolute uncertainty from the percentage uncertainty and express the quantity and its uncertainty correctly.
Q10	**Ans: C** Since P = I2R The percentage uncertainty of P = $\frac{\Delta P}{\text{P}} \times 100\% = \frac{2\Delta I}{\text{I}} \times 100\% + \frac{\Delta R}{\text{R}} \times 100\%$ = $2\left(\frac{0.05}{2.5}\right) \times 100\% + 2\%$ = 6 %	1	Students need to assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties or by simple numerical substitution.
Q11	**Ans: B** $\frac{\Delta \rho}{\rho} = 2\frac{\Delta d}{\text{d}} + \frac{\Delta V}{\text{V}} + \frac{\Delta L}{L} + \frac{\Delta I}{\text{I}}$ Thus, compare each of the term to find the least uncertainty: For diameter, $2\frac{\Delta d}{\text{d}} = 2\left(\frac{0.01}{1.20}\right) = 0.017$ For current, $\frac{\Delta I}{\text{I}} = \frac{0.05}{1.50} = 0.033$ For length, $\frac{\Delta L}{L} = \frac{1}{100} = 0.010$ For potential difference, $\frac{\Delta V}{\text{V}} = \frac{0.1}{5.0} = 0.020$ Hence, measurement in current gives rise to the least uncertainty in the value for the resistivity.	1	Students need to assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties or by simple numerical substitution.
Q12	Equation provided: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$		Student should know when to use the uncertainty formula and

	Apply the Extreme Values Method. Plugging in the highest value of u and v into the equation gives the highest value of f: $\frac{1}{53}+\frac{1}{205}=\frac{1}{f}$ and thus $f\ = 42.1$ Plugging in the lowest value of u and v into the equation gives the lowest value of f: $\frac{1}{47}+\frac{1}{195}=\frac{1}{f}$ and thus $f\ = 37.9$ So, f ranges from 37.9 to 42.1. The absolute uncertainty is found by: $\frac{Highest\ value\ of\ f - lowest\ value\ of\ f}{2} = \frac{42.1-37.9}{2} = 2.1$ Thus the absolute uncertainty of f is ±2 mm **(1 s.f.)**. **** Remember to include units!***	1 1 1	when to apply the Extreme Value Method. In this case, $\frac{1}{f}=\frac{u+v}{uv}$ $f=\frac{uv}{u+v}$ The product/quotient rule cannot be applied when the same variables appear in both numerator and denominator. Use the Extreme Values Method in this case. However, note that when using the Extreme Values method, use the equation in the original form given in the question. Do NOT use the equation in the form $f=\frac{uv}{u+v}$ whereby you will get uncertainty of 5 mm instead of 2 mm. This is because it doesn't make sense to substitute different values of u in the numerator and denominator since at any instant the two values of u should be the same. Likewise for values of v. E.g. to get maximum f, you cannot substitute maximum u in the numerator and minimum u in the denominator. There is an alternative method using the addition/subtraction rule and product/quotient

			rule. But this method proves more tedious: Method 2 -- Find the absolute uncertainties in 1/u and 1/v separately first. $\frac{\Delta\left(\frac{1}{u}\right)}{\left(\frac{1}{u}\right)} = \frac{\Delta(1)}{1} + \frac{\Delta u}{u}$ $\Delta\left(\frac{1}{u}\right) = \left[0 + \frac{\Delta u}{u}\right].\left(\frac{1}{u}\right) = \frac{\Delta u}{u^2} = 1.2x10^{-3}mm^{-1}$ Similarly, $\Delta\left(\frac{1}{v}\right) = \frac{\Delta v}{v^2} = 1.25x10^{-4}mm^{-1}$ $\Delta\left(\frac{1}{f}\right) = \Delta\left(\frac{1}{u}\right) + \Delta\left(\frac{1}{v}\right) = 1.325x10^{-3}mm^{-1}$ $\Delta\left(\frac{1}{f}\right) = \frac{\Delta f}{f^2}$ $\Delta f = \Delta\left(\frac{1}{f}\right).f^2 = 2\,mm\ (1\ s.f.)$ Absolute uncertainty must be rounded off to 1 s.f.
Q13	(a)(i) Using the ***average*** values of h & t. $h = \frac{1}{2}gt^2$ $g = \frac{2h}{t^2} = \frac{2 \times 2.66}{0.740^2} = 9.72\,m\,s^{-2}$	 1 1	It suffices to use the **average / mean** values of h & t. There is no need to compute maximum and minimum values of g and use the values to calculate the average value of g. Students should recall the meaning of number of significant values and quote answers accordingly.

	(a)(ii) 1. $\frac{\Delta h}{h}\times 100\% = \frac{1}{266}\times 100\% = 0.38\%$ (2 s.f) ***Feedback for Assignment:*** • *Several students wrote Δh or Δh/h on the left hand side of the equation, which resulted in a mismatch between the left hand side and right hand side. E.g.* $\Delta h = \frac{1}{266}\times 100\% = 0.38\%$ (wrong!!)	2	Students should recall and apply the correct equation for % uncertainty. Strictly speaking, final answer should be to 1 s.f. since Δh is in 1 s.f. However, this particular question stipulates expressing the answer in 2 s.f.
	(a)(ii)2. $\frac{\Delta t}{t}\times 100\% = \frac{0.005}{0.740}\times 100\% = 0.68\%$ (2 s.f.)	2	
	b) $h = \frac{1}{2}gt^2$ $g = \frac{2h}{t^2}$ $\frac{\Delta g}{g} = \frac{\Delta h}{h} + 2\frac{\Delta t}{t}$ $\Delta g = \frac{0.38 + 2(0.68)}{100}\times 9.72 = 0.169 = 0.2\,m\,s^{-2}(1s.f.)$ $\therefore (g \pm \Delta g) = (9.7 \pm 0.2)\,m\,s^{-2}$ ***Feedback for Assignment:*** • *An important step is to make the unknown (g) the subject in the equation before applying the product/quotient rule.* • *Many students did not include the units for Δg. Fractional uncertainty has no units but absolute uncertainty has units.* • *In the last step, many students wrote "g" instead of "g±Δg" on the left side of the equation:* "$g = (9.7 \pm 0.2)\,m\,s^{-2}$" (wrong!!)	 1 1 1	Students should remember and apply the uncertainty propagation formulae for products and powers. Before applying the formulae, make the unknown (g) the subject in the equation first. Students should remember that absolute uncertainty is quoted to 1 s.f. since it is an estimate and we can't be too precise about an estimate. Also, the g value is quoted to the same precision as the absolute uncertainty.
	c) t is precise due to more precise measuring instruments and technique used for time measurement in this experiment which allows for smaller uncertainty in the measurement. However t may be inaccurate due to systematic errors such as:		Students should recognise that **inaccuracies** are caused by **systematic** errors, and be familiar with common systematic errors in experimental setups.

	i. Zero error or miscalibration of the timer. Thus the reading obtained would either be always an overestimate or underestimate of the true value. ii. Arrangement of measuring instruments is another source of systematic error: The ball would have to be dropped **above** the upper photogate (the one that starts the timer); the initial position of the ball cannot be exactly at the photogate otherwise the timer would be started even before the ball is dropped. Hence the initial position of the ball must be slightly above the upper photogate. As such, **the ball would have gained some speed before starting the timer; i.e. the ball's speed WILL be non-zero when the timer is started.** Thus the time t for the ball to fall through distance h between the 2 photogates would **always** be shorter than the actual timing by a fixed amount, resulting in systematic error. ***Feedback for Assignment:*** • *Problematic explanation 1: "The height from which the ball is released through the photogate may differ for different measurements." → Problematic because this is a random error, not systematic error.* • *Problematic explanation 2: "Once the terminal velocity is reached, its speed remains constant which affects acceleration of the ball." → Problematic because unlikely that terminal velocity is reached since air resistance is negligible compared to the ball's weight, as well as, since the ball falls through a very short distance only.* • *Problematic explanation 3: "Wind may cause the ball to not travel in a straight line." → Problematic because, firstly, it is too silly an error to make by a trained physics experimenter. It is common sense to conduct the experiment in an environment without wind. Secondly, the metal ball is heavy, and thus any slight breeze would not affect its path significantly. Thirdly, wind has turbulence and can change direction during the motion of the ball, thus error likely to be random not systematic.* • *Problematic explanation 4: "End error of metre rule causes h to be underestimated." → Problematic because question asks for systematic error in t measurement, not h measurement. Although h affects t, in making the h measurement, other errors like parallax error and a non-vertical metre rule could affect h also. Thus the overall effect on t*	1 1	Notes: 1) As the time taken is very precise (Δt = 0.005), the reading should not be taken by a stopwatch. Therefore human reaction time is NOT acceptable as an answer. 2) Because it is a small and dense ball, and speeds achieved by the ball in this experiment is likely very low, the effect of air resistance on the ball's motion is unlikely to be significant. In fact, Cambridge did not accept this as an explanation. 3) Question defines t as the time taken when the ball is dropped **from rest**. Timer must be started at the instant ball is released **from rest** for an accurate measurement. 4) In fact, the ball would have to be dropped ABOVE the upper photogate (the one that starts the timer); the initial position of the ball cannot be exactly at the photogate otherwise the timer would be started even before the ball is dropped. Hence the ball must be released slightly above the upper photogate. As such, the ball would have gained some speed before starting the timer; i.e.

	measurement is not definitely skewed in one direction. Therefore, cite errors that affect t ***directly****.* • *Problematic explanation 5: "Photogates might not be exactly parallel to each other, or, may not be horizontal." → Problematic because this causes random error not systematic error.* *Top view of photogate:*  *Left end view of photogate:*  *(scenario 1: beams of both photogates are parallel and horizontal) – Regardless of the position of release of the metal ball, 1 or 2, distance between beams remains constant.*  *(scenario 2: beams are tilted, not parallel) – Depending on position of release of the metal ball, 1 or 2, distance h differs. Therefore it is a random error since position of the ball is random from measurement to measurement.*		the ball's speed WILL be non-zero when the timer is started. Thus the time t for the ball to fall through distance h between the 2 photogates would always be shorter than the actual timing, resulting in systematic error. 5) Note also that in the setup, the time t recorded by the timer will be the time taken for the ball to fall between the 2 photogates, since the timer is started only when the ball passes the upper photogate and stopped when it passes the lower photogate. Therefore h must be taken to be the distance between the 2 photogates. This means that measuring h from the initial position of the ball (i.e. above the upper photogate) instead of from the upper photogate would not be a solution to the systematic error.
Q14	**Ans: B** Since this a Number of readings vs x graph, • small spread in measurements on the graph - precise • average value is not close to true value (x_o) – not accurate	1	Students need to understand the distinction between precision and accuracy.

Q15

Ans: B

Smallest systematic error $\Rightarrow$ accurate readings. Hence we want readings which are accurate but not very precise.

Balance	Reading / kg					Mean / kg	Conclusion
	1	2	3	4	5		
A	1.000	1.000	1.002	1.001	1.002	1.001	P, A
B	1.011	0.999	1.001	0.989	0.995	0.999	NP, A
C	1.012	1.013	1.012	1.014	1.014	1.013	P, NA
D	0.993	0.987	1.002	1.000	0.983	0.993	NP, NA

First, we compare the mean value of each balance to the true value(1.000 kg). Option A or B has the same smallest systematic error (0.001 kg)

Then we compare the range of the readings for each balance, Option A has a smaller range (0.002 kg) than Option B (0.022 kg). Option A is more precise Option B.

Hence Option B is the answer: smallest systematic error but not very precise.

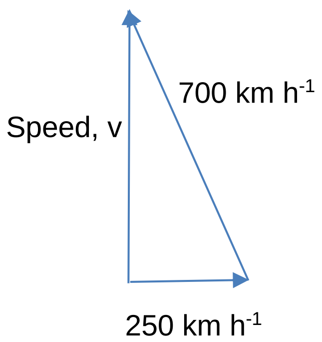
1

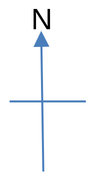
Students are to be familiar with how systematic error manifests in actual data (difference between mean and actual value)

Students are also to be familiar with recognising precision (spread in the data)

Q16

Answer: B

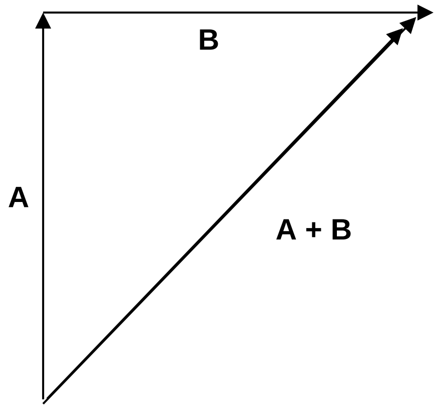
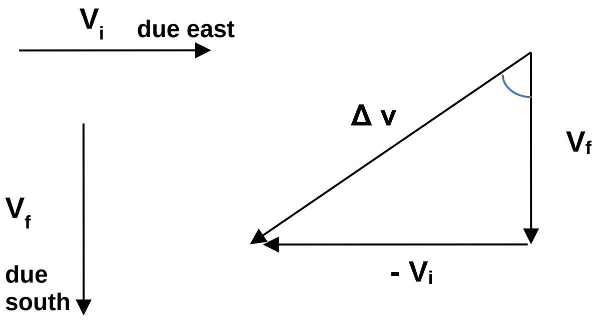




This question is asking students to find the magnitude of the resultant velocity of the aircraft. Do draw a vector diagram to better understand what the question is asking for. Since the vector diagram is of a right angle triangle, we can use Pythagoras theorem to solve for speed v.

$v^2 + 250^2 = 700^2$

$v = \sqrt{700^2 - 250^2} = 650\ km/h$

Q17	(a) 	2	Students should know to use scaled vector triangles to find the sum of two vectors. Students should also know that scale is important for vector diagrams and use double arrows to indicate the resultant vector. Students can also use the parallelogram method to find the resultant.
	(b)(i) 	2	Students should know how to find changes in vector quantities. Particularly, they should to draw out the diagram that describe the question and know reverse the direction for initial velocity vector. Finally, they should use addition vectors diagram to find Δv.
	(b)(ii) Change in Speed = 25 – 30 = - 5 m s^{-1}	1	Students should recognise speed is scalar quantity.
	(b)(iii) Magnitude $\lvert\Delta v\rvert = \sqrt{(v_i^2 + v_f^2)}$ $= \sqrt{(30^2 + 25^2)}$ = 39 m s^{-1} Direction = $\tan^{-1}(v_i / v_f)$ = $\tan^{-1}(30/25)$ = 50.2° Hence it is 50.2° W of S.	 1 1	Students should: 1) know to find the magnitude of the resultant vector by Pythagoras' Theorem 2) know to find the direction from the inverse tangent equation
	(b)(iv) The answers are different, as speed is a scalar and velocity is a vector. For speed, direction is not important, but for velocity, we need to take into consideration of its direction.	1 1	Student should understand the difference between vector and scalar quantities.

	Assignment Questions		SIOs / Notes
A1	**Ans: D** $Intensity = \dfrac{Energy}{Area \times time}$ [Intensity] = {[Force][distance]}/{[area][time]} = (kg m s^{-2} x m) / (m^2 x s) = kg s^{-3}	1	Students need to express derived units as products or quotients of the base units and use the named units listed in 'Summary of Key Quantities, Symbols and Units' as appropriate.

A2	a) $\dfrac{\Delta L}{L} = \dfrac{1}{297} = 0.00337 = 0.003$ (1s.f.)	2	Answer should not be in fraction, but always in decimal.
	b) $\dfrac{\Delta L}{L} \times 100\% = 0.337\% = 0.3\%$ (1 s.f.)	2	Students need to know how to calculate absolute uncertainty in a derived quantity and express the quantity and its uncertainty correctly.
	c) $A = Lb = 297 \times 209 = 62073\,mm^2$ $\dfrac{\Delta A}{A} = \dfrac{\Delta L}{L} + \dfrac{\Delta b}{b} = \dfrac{1}{297} + \dfrac{1}{209}$ $\Delta A = 8.15 \times 10^{-3} \times 62073 = 506\,mm^2$ ΔA to 1 sf is $500\,mm^2$. But we should not write $(A \pm \Delta A) = (62073 \pm 500)\,mm^2$ even though A has the same number of decimal places as ΔA, because $(A \pm \Delta A) = (62073 \pm 500)\,mm^2 = (6.2073 \pm 0.05) \times 10^4\ mm^2$ in standard form, which does not obey the rules. Instead we should write $(A \pm \Delta A) = (62100 \pm 500)\,mm^2 = (6.21 \pm 0.05) \times 10^4\ mm^2$. This is consistent with the rules.	1 1 1	
	d) Assuming the thickness of paper is 0.1 mm The diameter of an atom = 10^{-10} m No. of atoms along the length of paper = 297 x 10^{-3} / 10^{-10} = 2.97 x 10^9 No. of atoms along the width of paper = 209 x 10^{-3} / 10^{-10} = 2.09 x 10^9 No. of atoms along the thickness of paper = 0.1 x 10^{-3} / 10^{-10} = 1 x 10^6	1 1	Student needs to make reasonable estimates of physical quantities included within the syllabus

	Total number of atoms = $(2.97 \times 10^9)(2.09 \times 10^9)(1 \times 10^6)$ = 6×10^{24} (1 s.f.)	 1 1	

A3	(a) [ ] represents "units of" $[f^2] = [a]/[L]$ $[a] = (s^{-2})\ (m) = s^{-2}\ m$	 1 1	Students need to observe the units given on the graph, understand the relationship of the equation and bear in mind not all constants are dimensionless. Ensure correct use of [ ] which represents "units of". [ ] should only be around a physical quantity, not around units.
	(b) Small systematic error as the graph shows that the **experimentally obtained** line of best-fit passes very close to the **origin**, **which is the expected axes-intercept** in the absence of error based on the **theoretical equation**.	1 1	In contrast, if the experimentally obtained line of best-fit is significantly far away from the origin, then systematic error is significant. Students need to see the connection between the presence of systematic error and a constant shift in all measured values from the theoretically expected values. Students need to distinguish clearly between what is "experimentally obtained" and what is predicted from "theory".
	(c) To reduce the <u>effect of</u> random error through averaging. It is also possible to identify the presence of systematic error and hence correct it.	1	Random error cannot be avoided. But its effect can be reduced via averaging / drawing best-fit line.

	Supplementary Questions		SIO/ Notes

S1

a.	3	e.	3	i.	1 or 2 or 3
b.	3	f.	3	j.	3
c.	3 or 4	g.	2	k.	3
d.	5	h.	4	l.	3

S2

a.	846 (3s.f.)	e.	0.2 (1 d.p.)
b.	7.9 (1 d.p.)	f.	0.738 (3 s.f.)
c.	840 (2 s.f.)	g.	5.77 (3 s.f.)
d.	1110 (3 s.f.)	h.	7.788 (4 s.f.)

S3

a.	9.827×10^{3}	d.	1.5×10^{6} (2 s.f.)
b.	5.50×10^{-7}	e.	2.6×10^{-5} (2 s.f.)
c.	3.2×10^{6}	f.	1.6×10

S4

(a) [3]

Base quantities	**Base units**
Length	metre
Mass	kilogram
Time	second
Temperature	kelvin
Electric current	ampere
Amount of substance	mole
Luminous intensity	candela

SIO/ Notes: Students need to be familiar with the 7 base quantities, and be told that all quantities expressed in base units MUST be expressed in terms of these 7 units.

(b) (i)

Units of Energy = Units of Work

Work = force x displacement moved in the direction of force [1]

W = F x d

[W] = [F] x [d]

= [ma] x [d]

= kg x m s^{-2} x m

= kg m^{2} s^{-2} [1]

(ii)

$F = BIL$ [1]

$B = \dfrac{F}{IL}$

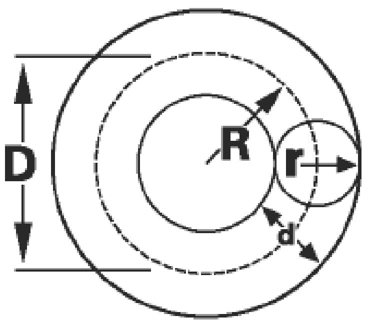
$[B] = \dfrac{[F]}{[I][L]} = \dfrac{kg\,m\,s^{-2}}{A\,.\,m} = kg\,s^{-2}\,A^{-1}$

SIO/ Notes: Students are to recognise that the derived units are to be calculated from their defining equations

S5

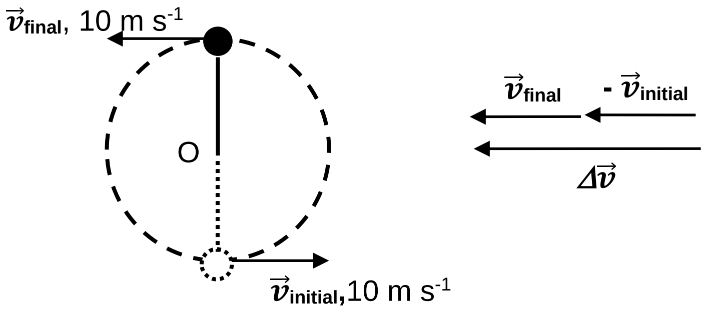
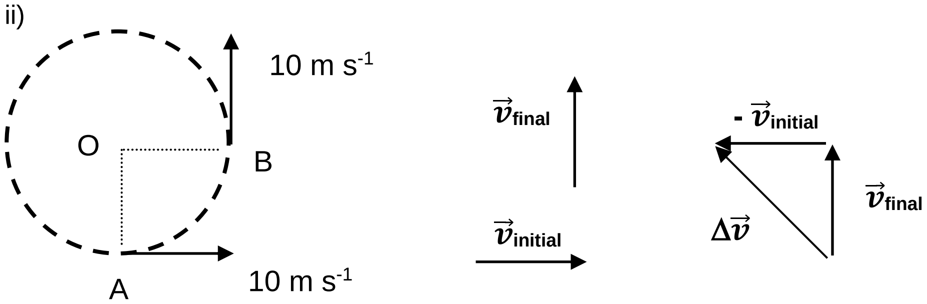
Prefix	Decimal equivalent	
Pico	**10^{-12}**	1
Micro	10^{-6}	
Giga	**10^{9}**	1
Tera	10^{12}	1

SIO/ Notes: Students are to be familiar with the prefixes and their corresponding order of magnitude factors

S6	a. 9.12×10^{-6} s b. 3.42×10^{3} m c. 4.4×10^{-3} m d. 55 cm / ms = $5.5 \times 10^{-3} / 10^{-3}$ = 5.5 m/s e. 80 km/ hr = 80×10^{3} / (60 x 60) = 22 m/s f. 60.5 cm^2 = $60.5 \times (10^{-2})^2 = 60.5 \times 10^{-4}$ m^2 g. 50.9 mm^3 = $50.9 \times (10^{-3})^3 = 50.9 \times 10^{-9}$ m^3 h. 70.1 g mm^{-3} = $70.1 \times 10^{-3} / 10^{-9} = 70.1 \times 10^{6}$ kg m^{-3} i. 30 years = 30 x 365 x 24 x 60 x 60 = 950×10^{6} s		Students need to use the prefixes and their symbols.
S7	**Ans: D** 1) How do we know if the given kinetic energy of the bus is reasonable? • It is difficult to guess just the kinetic energy, but it is easier to estimate the mass and speed of the bus. Assuming that the mass of bus is approximately 10 000 kg and speed of bus cannot exceed the speed limit of 70 km/h, the kinetic energy of the bus is roughly = ½ (10000)(70 x 1000/3600) = 97 000 J 2) How do we know if the power rating of a domestic light is reasonable? • Available domestic light in the market are unlikely to be as high as 300 W, mostly are 5 W – 100 W. 3) How do we know if the temperature of a hot oven is reasonable? • 300 K = 27 °C, and this is definitely not HOT. 4) How do we know if the volume of air in a car tyre is reasonable? • To find the volume of air, we just need to find the volume of tyre as air takes up space in the tyre. • To find the volume of tyre, we can use the formula $2\pi^2 Rr^2$, where R is the radius from the centre of the tyre to the median of the tyre and r is the radius of the cross-sectional area of the tyre. Estimating the diameter of the tyre is around 50 cm, R is about 20 cm. And the widen of the tyre is approximately 15 cm, hence r is approximately 7.5 cm. • Calculate the volume = 22 206 cm^3 = 0.02 m^3 	1	Students need to make reasonable estimates of physical quantities included within the syllabus.

	Thus, the volume of air in a car tyre is the closest approximation.		
S8	**Ans: B** Percentage uncertainty of $\frac{xy^2}{z}$ $= \frac{\Delta x}{x} \times 100\% + 2\left(\frac{\Delta y}{y}\right) \times 100\% + \frac{\Delta z}{z} \times 100\%$ Hence the combination that makes the percentage uncertainty equals to 6% is option B.	1	Students need to assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties or by simple numerical substitution.
S9	$Q = k\frac{r^3(p_1 - p_2)}{L}$ $p_1 - p_2 = 125 - 100 = 25\,kPa$ $\Delta(p_1 - p_2) = \Delta p_1 + \Delta p_2 = 1 + 1 = 2\,kPa$ $\frac{\Delta(p_1 - p_2)}{(p_1 - p_2)} = \frac{2}{25} = 0.08$ $\therefore \frac{\Delta Q}{Q} = 3\frac{\Delta r}{r} + \frac{\Delta(p_1 - p_2)}{(p_1 - p_2)} + \frac{\Delta L}{L} = 3\left(\frac{0.03}{1.55}\right) + 0.08 + \frac{5}{120} = 0.2(1s.f.)$	1 2	Students can let y be ($P_1 - P_2$). So if $y = P_1 - P_2$, then finding Δy and hence Δy/y will be easier. Absolute, fractional and percentage uncertainties should be expressed to 1 sig. fig.
S10	**Ans: D** Let $r = d_1 - d_2 = 64 - 47 = 17$ $\Delta r = \Delta d_1 + \Delta d_2 = 2 + 1 = \pm 3$ mm $\frac{\Delta r}{r} \times 100\% = \frac{3}{17} \times 100\% = 17.6\% = 18\%$ (2sf)	1	Students need to know how to calculate percentage uncertainty in a derived quantity.
S11	**Ans: A** Make g as the subject, $$g = 4\pi^2\left(\frac{L}{T^2}\right)$$ Hence, percentage uncertainty of g $= \frac{\Delta L}{L} \times 100\% + 2\left(\frac{\Delta T}{T}\right) \times 100\%$ Therefore, $2\% = \frac{0.05}{6.25} \times 100\%$ + 2 x (percentage uncertainty of T) Percentage uncertainty of T = 0.6 %	1	Students need to assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties or by simple numerical substitution.
S12	Fractional uncertainty of η, $\frac{\Delta\eta}{\eta} = 2\left(\frac{\Delta r}{r}\right) + \frac{\Delta v}{v}$ $= 2\left(\frac{0.01}{0.83}\right) + \frac{0.002}{0.065}$ = 0.055 Therefore, absolute uncertainty of η,	1	Students need to assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties or by

	$\Delta\eta = 0.055 \times \frac{kr^2}{v}$ $= 0.055 \times 93.7\ (0.83 \times 10^{-3})^2 / 0.065$ $= 5 \times 10^{-5}$ kg m^{-1} s^{-1} η = (90 ± 5) x 10^{-5} kg m^{-1} s^{-1} or (9.9 ± 0.5) x 10^{-4} N m^{-2} s	2 1	simple numerical substitution.
S13	**Ans: A** The rest of options are attempted to reduce the effect of random errors.	1	Students need to show an understanding of the distinction between systematic errors (including zero errors) and random errors.
S14	**Ans: C** Precision is related to random error. For high precision, it means that the readings have low random error (hence readings are more précised). Accuracy is related to systematic error and hence low accuracy refers to high systematic error (average value of readings deviate from the true value).	1	Students need to show an understanding of the distinction between systematic errors (including zero errors) and random errors and show an understanding of the distinction between precision and accuracy.
S15	**Ans: C** Random errors may be identified and its effect reduced but cannot be avoided (inherent in the measurement process; the scattering on the graph remains). The scatter of the readings on the graph identifies random errors. Drawing the line of best fit has the same effect as taking average. Thus, this will help to reduce the effects of random errors (Not Option A) It is also possible to identify "out of trend" or poor readings (Not Option B) If there is a systematic error, the readings will consistently be larger or smaller than the true readings. Consequently, the line of best fit will be shifted in a particular direction by a particular amount on the graph. Thus, it may be possible to identify systematic error and systematic error can be corrected by either adding (if negative error) or subtracting (if positive error) the difference between the line of best fit and the theoretically expected line. (Not Option D)	1	Students need to distinguish that random errors cannot be eliminated.

S16	***Recall that 'Difference of velocity' / 'Change in velocity' is also a vector. Whenever you are asked to determine a vector, specify both magnitude & direction.*** i) 	1
	Difference in velocity = $\vec{v}_{final} - \vec{v}_{initial} = \vec{v}_{final} + (-\vec{v}_{initial})$ = 10+ 10 = 20 m s^{-1} in the direction of $\vec{v}_{final}$.[1]	1
	ii) 	1
	Change in velocity, $\Delta\vec{v} = \vec{v}_{final} - \vec{v}_{initial} = \vec{v}_{final} + (-\vec{v}_{initial})$ $\lvert\Delta\vec{v}\rvert = \sqrt{(10^2 + 10^2)}$ = 14.1 m s^{-1} Direction of $\Delta\vec{v}$: 45^{O} counter-clockwise of $\vec{v}_{final}$.	1 1

[1] 'Difference of velocity' / 'Change in velocity' is also a vector. Whenever you are asked to determine a vector, specify both magnitude & direction.