Mark schemes

Q1.

(a) calculates, using all 4 values, a mean of 0.418 (s) ✓

Expect to see 25.08 (mean average) divided by 60, or 100.32 (sum) divided by 240 in working

1

(b) 2.75 cycles (between **P** and **Q**) $_1$✓

T_{PQ} = 0.42 × their number of cycles $_2$✓

Expect T_{PQ} = 1.15, 1.16 or 1.2 (s)

$_2$✓ *Allow use of >2 sf T_{PQ} that rounds to 0.42 (s)*

$_2$✓ *Their number of cycles must be between 2.5 and 3*

2

(c) 0.170 (m) ✓

Condone 2 sf value on answer line if working shows a 3 sf value or "170 mm" seen or "20 mm" used e.g. '8.5 × 20 mm'.

1

(d) correct use of an appropriate equation of motion $_1$✓

correct evaluation of their *a* $_2$✓

Expect to see a = 0.24, 0.25 or 0.26 (m s^{-2})

$_1$✓ *Expect* $a = \frac{2 \times \text{their } s}{\text{their } (T_{PQ})^2}$ ***OR***

mean $v = \frac{\text{their } s}{\text{their } T_{PQ}}$ ***AND*** $a = \frac{2 \times \text{their mean } v}{\text{their } T_{PQ}}$

Expect mean v = 0.14 or 0.15 (m s^{-1})

$_1$✓ *Allow s in mm*

2

(e) links (absolute) uncertainty of 1 mm for one reading to the resolution of 2 mm of the graph paper $_1$✓

$_1$✓ *Condone 'uncertainty in a single reading is half a grid division'*

idea that *s* is based on two readings so (absolute) uncertainties in each reading are added $_2$✓

$_2$✓ *Allow 's is based on two readings so uncertainty in s is double the uncertainty of each reading'*

2

(f) $\frac{0.002}{their\ s} \times 100$

OR

2 × 0.46 or 0.92 seen $_1$✓

Expect to see % uncertainty in a = 2.1

$_1$✓*Expect % uncertainty in s = 1.2. Calculator value is 1.17647.*

$_1$✓*Allow values in mm*

% uncertainty in *a* = (their % uncertainty in *s*) + 0.92 $_2$✓

$_2$✓ *Allow 1 or 2 sf values only*

2

[10]

Q2.

(a) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

Mark	Criteria
6	All three areas covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed, or makes a partial attempt at two areas.

1	None of the three areas covered without significant error.
0	No relevant analysis.

Method
Field is off or with the switch open
Measure time and distance (for falling drop) (Measure distance using lines on microscope) calculate velocity using $v = \frac{s}{t}$
Calculation
(Just quoting formulae from the formulae and data booklet is not enough to partially address this area.)
$m = \frac{4}{3}\pi\rho r^3$
$mg = 6\pi\eta rv$
leading to $r = \sqrt{\frac{9\eta v}{2\rho g}}$
or $r = \sqrt{\frac{9\eta v}{2\rho g}}$ quoted
ρ is identified as the density of the **oil**
η is identified as the viscosity of the **air**

Principles/Assumptions
(This area is normally fully addressed by 2 statements.) Falls at terminal velocity since weight = viscous drag force / Stokes' law Air acts like a viscous fluid so Stokes' law applies.
Balanced forces according to Newton 1 or 2
Oil droplet is spherical (hence $V = \frac{4}{3}\pi r^3$)
Upthrust is negligible / can be ignored.
Any mention that air resistance is negligible or not present when field is off would not allow this area to be fully addressed.
Ignore reference to free fall.
Ignore details of Millikan's experiment that are not about determining *r*.

6

(b) Max ✓✓

- Substitution into $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times (1.2 \times 10^{-6})^3$
- Substitution of $m = \rho$ = 880 × their volume
- Substitution of $Q = \frac{dmg}{V} = \frac{6.0\times10^{-8}\times \text{their mass} \times 9.81}{467}$

Max 2 if no equations are seen but only substitution (one for a correct substitution and one for correct answer)

MP1 and MP2 require substitutions.

$Q = 8.0(3) \times 10^{-19}$ (C) ✓

Need ≥ 2 sf (no ecf in mp3)

3

(c) % uncertainty in Q = 3 × 4 + 1 + 0.1 + 0.2 + 2 = ((±)15(.3)%) ✓1a

Allow fractional uncertainties in ✓1a

uncertainty in $Q = \frac{15}{100} \times 8.02 \times 10^{-19} = (\pm)1.2 \times 10^{-19}$ (C) ✓2a

Alternative method for ✓1 and ✓2

max value of Q = $\frac{4\pi \times (1.2\times10^{-6}\times1.04)^3 \times 880 \times 1.01 \times 6\times10^{-8} \times 1.02 \times 9.81 \times 1.001}{3\times467\times0.998}$

(= 9.3(3) × 10^{-19} C)

OR

min value of Q = $\frac{4\pi \times (1.2\times10^{-6}\times0.96)^3 \times 880 \times 0.99 \times 6\times10^{-8} \times 0.98 \times 9.81 \times 0.999}{3\times467\times1.002}$

(= 6.8(7) × 10^{-19} C)✓1b

Correct use of max or min value with 8(.02) × 10^{-19} or half the range using max and min

if their max and/or min comes from a correct method with up to one error in each✓2b

Allow ecf for Q and % uncertainty

✓3 is independent if 1 × 10^{-19} is used or an answer that rounds to 1 × 10^{-19}.

Alternatives for ✓3

the possible range overlaps 4, 5, 6 electrons (allow 4, 5 or 5, 6 or 4, 6)

Allow a calculated max and/or min value of Q (8 ± 1) × 10^{-19} (expect 7 or 9) is not an (integer) multiple of 1.6 × 10^{-19}

Condone because the uncertainty (not % uncertainty) is too close to 1.6 × 10^{-19}.

Range or uncertainty or % uncertainty is too large is not enough without explicit comparison of absolute uncertainty with 1.60 × 10^{-19} in some form.

$1.2 \times 10^{-19} > \frac{1.60 \times 10^{-19}}{2}$

therefore it is not possible to confirm charge quantisation (as any value is possible) ✓3

3

[12]

Q3.

(a) 6.75 ✓

CAO

1

(b) any sensible answer describing possible consequences of use of the thimble, e.g. can cause the wire to be distorted/damaged; or reduces the diameter. ✓

Accept 'the frame of the micrometer might become warped' / 'damage might occur to the screw thread mechanism' / 'may lead to the reading shown being smaller than true value'

Condone 'squeezed'. Condone 'change diameter'.

Reject 'might change the reading', 'affect results', 'cause a reading below zero', 'could lead to systematic error', 'over-tighten' or 'holds wire more securely'.

1

(c) fully correct calculation $_1$✓$_2$✓

OR

partly correct calculation $_{12}$✓

((2 × 1.2%) + 2.0% =) 4.4% $_1$✓$_2$✓

*For $_{12}$✓ allow any of (2 × 1.2%) **OR** 2.4% **OR** 1.2% + 2.0% **OR** 3.2% **OR** 1.44% + 2.0% **OR** 3.4% seen in working.*

*For 1 mark condone misreading leading to '(2 × 2.0%) + 1.2% = 5.2%' **OR** '4% + 1.2% = 5.2%'.*

2

[4]

Q4.

(a) idea that absolute uncertainty is the same but value of *t* is larger ✓

Allow sample calculation or reference to equation.

Condone 'uncertainty' for 'absolute uncertainty'.

1

(b) draw a best-fit curve/line and read-off (*α*) where value of *t* is a minimum $_1$✓

For $_1$✓ 'draw a line' is not enough.

Accept read off at 'bottom of curve' / 'where the gradient is zero' / 'at the turning point'.

Annotations to Figure 8 can earn MP1; any line of best-fit drawn does not need to be neat.

take more readings around *α* when *t* has minimum value, or words to that effect (owtte) $_2$✓

For $_2$✓ reject bland 'repeat readings'.

2

[3]

Q5.

(a) idea that moments are balanced or that there is no resultant moment ✓

Answer must relate to the context e.g. reference to ***Q*** *or weight of food/spoon*

Allow 'force × distance' or 'F × d' for 'moment'.

(because)

(overall) centre of mass is now beneath/at **Q**

OR

line of action of (overall) weight is through **Q** ✓

'Anticlockwise moment of weight of spoon about ***Q*** *= clockwise moment of weight of M about* ***Q****' gains both marks.*

2

(b) statement of balanced moments seen e.g. $mgx = Mg(16 - 4 - x)$, leading to required formula ✓ ✓

For 1 mark: condone absent g if credible evidence for '12 - x' presented e.g. mx = M(16 - 4 - x) or mx = M(28 - 16 - x)

OR

condone lack of evidence for '12 - x' if g is shown e.g. mgx = Mg(12 - x).

Need to see g and evidence for '12 - x' for both

marks. Evidence for '12 - x' need not be in an expression of a moment.

Allow 9.81 or 9.8 instead of g.

2

(c) max two from: ✓ ✓

- reads off a pair of values (e.g. 115 g, 5.0 cm)
- substitutes into formula
- multiplies their *m* by *g*

answer that rounds to 1.5 or 1.6 (N) ✓

Allow correct conversion of M to kg and/or x to m for read offs or in the substitution.

Expect to see 160 g for mass of spoon.

Allow credit for an algebraic solution to get m:

$$\frac{m}{M} = \frac{(12-x)}{x}$$

e.g. when m = M, $= 1$

So, 12 = 2x, x = 6.0 cm. Reads off M at 6.0 cm to get 160 g.

3

(d) (absolute) uncertainty in *M* increases as *M* increases ✓

(because) as *M* increases:

marks on the scale get closer **OR** range of values of *M* for a fixed range of *x* increases (or vice versa) ✓

the gradient (in Figure 3) increases so the scale markings are unequal owtte ✓

MP1 only awarded supported by some relevant explanation. Treat 'percentage' uncertainty as neutral.

*Allow MP2 and MP3 for quantitative evidence given using Figure 3 e.g. from 0 g to 25 g, Δx ~ 1.5 cm; from 175 g to 200 g, Δx ~ 0.4 cm **OR** calculates gradients at low and high M.*

3

[10]

Q6.

(a) search coil is not suitable or wtte:

no <u>emf</u> (would be induced in a search coil) $_1$✓

$_1$✓and $_2$✓ can be earned independently but are contingent on a statement that the search coil is not suitable;

insist on suitable use of the appropriate underlined term

for $_1$✓condone 'potential difference' OR 'voltage' for emf

1

a search coil needs (to be cut by) changing <u>flux</u>

OR

search coil is not cut by changing <u>flux</u>

OR

<u>flux</u> (cutting coil) is constant or wtte $_2$✓

for $_2$✓ accept ϕ for flux;

do not insist on 'flux linkage';

do not allow 'field' for 'flux';

'current (in the coil on frame) must be ac' is neutral;

the suggestion that a search coil cannot be connected to a data logger is neutral

1

alternative approach:

search coil **is** suitable or wtte:

suggests a valid method that changes the flux cutting the search coil eg rotate either coil / turn (dc) current off / move either coil relative to other coil $_1$✓

states their method changes <u>flux</u> through search coil

OR if search coil is cut by changing <u>flux</u> or wtte $_2$✓

alternative approach:

$_1$✓ and $_2$✓ can be earned independently but are contingent on a statement that the search coil is suitable

(b) use of 1 - cos 25(°) or 1 - sin 65(°) in a calculation of percentage change $_1$✓

for $_1$✓ expect either ≥ 3 sf rounding to 1 - 0.906 OR 1 - 0.91 seen in working

OR 100 - 90.6 or 100 - 91 seen in working;

(-) 9.4 (%) CAO $_2$✓

for $_2$✓ expect min 2 sf rounding to (-) 9.4;

allow (-) 9.0 if 1 - 0.91 seen in working;

do not insist on minus sign or 'decrease' on answer line

allow $_2$✓ for unsupported answer of (-) 9.4;

if no other mark is awarded allow 12✓ use of 1 - sin 25(°) or 1 - cos 65(°) in a % difference calculation leading to 58%

2

(c) uncertainty (in a single reading / judgement) is ½° $_1$✓

for $_1$ ✓accept 0.5 seen in numerator of % calculation OR absolute uncertainty is 2×0.5;

allow a larger uncertainty up to 3° if justified with a comment about difficulty in judging the reading due to parallax, thickness of frame etc

1

(measurement of) θ is based on (difference between) <u>two</u> readings / judgements

OR

absolute uncertainty in θ (or $\Delta\theta$) = 2 × uncertainty in each reading / judgement $_2$✓

for $_2$ ✓accept 2×0.5 OR 2 × their uncertainty in (a single) reading seen in numerator OR evidence for use of 2 × their uncertainty in result of % calculation;

'measured twice' is ambiguous

correct percentage uncertainty calculation based on 100 × their absolute uncertainty divided by 25 $_3$✓

for $_3$ ✓ allow 1 sf result;

$\frac{2 \times 0.5}{25}$ *×100 = 4% (use of 0.5°) earns $_1$✓$_2$✓$_3$✓*

$\frac{0.5}{25}$ *×100 = 2% (missing 2×) earns $_1$✓$_2$✗$_3$✓*

$\frac{2 \times 1}{25}$ *× 100 = 8% (1° unexplained) earns $_1$✗$_2$✓$_3$✓*

$\frac{1}{25}$ *× 100 = 4% (1° unexplained) earns $_1$✗$_2$✗$_3$✓*

$_{123}$✓✓✓ for two-judgement explanation leading to 1° used in a correct % uncertainty calculation

2

[7]

Q7.

(a) correctly identifies error $_1$✓

*for $_1$✓ reading has been taken at / from the top of the **meniscus** / top of coloured oil / top of liquid*

OR

*should have taken / did not take reading from the bottom / lowest point of the **meniscus** / lowest point on **surface** of coloured oil*

OR

'(student thinks) sub-divisions are 0.1 cm^3 and not (as question states) 0.2 cm^3'

reject 'should have read from bottom of coloured oil' / 'failed to read meniscus properly' / 'read at the top of the air' / 'has read divisions incorrectly' or wtte

1

correct reading is 35.8 $_2$✓

for $_2$✓ CAO

1

(b) gradient from Δ log(V / cm^3) divided by Δ log(p / MPa); evaluated to ≥ 3 sf result between −1.05 and −1.01 $_1$✓

don't insist on large steps / read off accuracy

accept result that rounds to 3sf between −1.05 and −1.01; sign essential

1

relevant algebra enabling comparison with $y = mx + c$ $_2$✓

for $_2$✓ (eg Boyle's Law written as)

log V = − log p + constant

condone variation based on Ideal Gas Law in which case must establish that $(nR)T / (Nk)T$ is constant (which then implies Boyle's Law) (recognisable data book symbols only)

OR

*(**Figure 5** shows)*

log V = gradient × log p + constant;

accept (log) k, (log) c etc as recognisable symbols for the constant;

condone (any) numerical value given for the constant eg $10^{1.685}$;

accept m as recognisable symbol for the gradient

1

why gradient ≈ −1 confirms Boyle's Law $_3$✓

for $_3$✓ allow gradient is / equals / should be −1

if $_2$✓ not given accept 'gradient ≈ −1 demonstrates inverse proportion or wtte

1

(c) reads off and attempts to make use of log p_1 AND log V_1 for any point on the line $_1$✓

for $_1$✓ check log V_1 is within half a grid square of correct position for their log p_1 or vice-versa;

'make use of' excludes use in a gradient calculation

V_2 in range 10.5 to 11.5 (cm^3) earns $_1$✓$_2$✓$_3$✓

1

applies a workable method $_2$✓

for $_2$✓ creditworthy examples are

*a calculation of the intercept in **Figure 5***

eg log V + log p = 0.585

OR

use of gradient = $\frac{\Delta \log V}{\Delta \log p}$ *(eg similar triangles idea)*

OR

a calculation of $p \times V$ *(by any means)*

OR

use of log $V = -1 \times \log 0.34$ *+ their intercept*

no credit for claiming 1.685 (or 1.170) are intercepts; this cannot earn $_2$✓

1

further manipulation to determine unknown V_2 $_3$✓

for $_3$✓ *accept result that rounds to 10.5 or 11.5;*

accept 2sf 11 (cm^3)

1

(d) temperature (of air) $_1$✓

for $_1$✓ *accept 'mean ke of air molecules' (or wtte) / vapour pressure <u>of air</u>'*

'keep mass of air constant' is neutral (this information is given below ***Figure 5****)*

1

change the pressure of the gas slowly or wtte

OR

wait (after a change) between taking readings / until the oil level stabilises $_2$✓

award of $_2$✓ *is contingent on valid* $_1$✓

for $_2$✓ *condone 'keep lab temperature constant';*

'use a water bath' is neutral

reject 'do the experiment slowly' / 'do not heat the apparatus' / 'keep windows closed' etc

1

[10]