Mark schemes

Q1.

(a) $\lambda = 2 \times 0.648$

Allow 1296 (mm) or 1.296 (m) or 129.6 (cm) seen.

OR

Use of $v = f\lambda$ ✓

*Condone **one error** in their substitution where λ and f have been substituted and v would be the subject:*

Allow

(v=) 0.648 x 147 (forgets to double L)

OR

$(v=)\frac{0.648}{2}$ x 147 (halves L)

Do not allow:

*(v=) 648 x 147 (POT error **and** forgets to double L)*

NOR

$(v=)\frac{648}{2}$ x 147 (POT error **and** halves L)

(v =) 191 (m s^{-1}) ✓

Calculator display= 190.512

190 (ms^{-1}) correct to 2 sf

2

(b) Use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

OR

Use of $v = \sqrt{\frac{T}{\mu}}$

OR

*Condone **one error** where f, l and T have been substituted.*

OR

μ would be subject of a correctly rearranged expression $(\mu=)\frac{T}{4l^2f^2}$

(μ=) 1.956×10^{-3} (kg m^{-1})✓

Their l:

*must be seen in **MP1**:*

or

*condone a POT error (if already penalised in **MP1** or part (a))*

Use of

m = their *μ* × *their l* ✓

allow ecf from part ***(a)*** *where* $v = \sqrt{\frac{T}{\mu}}$ *seen*

MP1 $\mu = \frac{T}{v^2}$ *or μ = 71 / answer to part (a)*

MP2 *(m=) their ecf μ × 0.648*

MP3 ecf answer

(*m* =) 1.3×10^{-3} (kg) ✓

Calculator display= $1.267618831 \times 10^{-3}$ *(kg)*

3

[5]

Q2.

(a) between *s* = 7.5 m and *s* = 15 m ✓

Tick in 2nd box only

1

(b) Use of $\Delta E_P = mgh$ ✓

Use of: rearrangement where m would be subject or substitution.

Condone ***one error*** *in substitution.*

(*m* =)65(.0) (kg) ✓

Calculator display =

For g = 9.81 ms^{-2} *= 64.96772001*

For g = 9.8 ms^{-2} *= 65.0340136054421*

Alternative method for an ECF from ***part (a)*** *(tick in 3rd or 4th boxes).*

- *Use of* $E_k = \frac{1}{2}mv^2$

  OR

  Read-off for v = 15.4 ms^{-1} *(Acceptable range 15.2* ms^{-1} *to 15.6* ms^{-1}*)*
- *m= 80.6 (kg)*

(Acceptable range 78.57 kg to 82.76 kg)

2

(c) Max 2 from: ✓✓

- Energy difference (E) = 9.56 - 7.71 = 1.85 (kJ) ✓

  Accept correct energy conservation statement for ***MP1***

  For example:

  $\Delta E_P = E_K$ *+ energy stored (in rope)*

- Use of $E = \frac{1}{2}k\Delta L^2$

  Use of:

  Rearrangement to make ΔL the subject or by substitution.

  Condone use of their E and **one other error** *in substitution. (allow 9.56 (kJ) or 7.71(kJ) for E)*

  Condone use of

  $E = \frac{1}{2}F\Delta L$ ***and*** *F = kΔL* ***OR***

  $E = \frac{1}{2}F\Delta L$ ***and*** *F=mg*

With their F and their E seen in $E = \frac{1}{2}F\Delta L$

- $\Delta L = \sqrt{\frac{2 \times their\ energy\ difference}{k}}$

  Must be an energy difference. Condone POT
  Do not accept 9.56 (kJ) or 7.71(kJ) for their energy difference.

ΔL = 5.8(0) m ✓

Max 1 mark for:
637.65 = 110 × ΔL giving ΔL = 5.8 m
must be done by considering energy transfers.
OR
answer without working.

[6]

Q3.

(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

[6]

Q4.

(a) value in range 2.9×10^4 to 3.0×10^4 (N) ✓

Use of data from any point (plotted or using their line or using their B for brass) is acceptable

1

(b) smooth curve through at least 4 saltires $_{1a}$✓

$_{1a}$✓ *Reject thick or discontinuous lines*

$_{1a}$✓ *can be awarded if no credit gained in* $_{1b}$✓ *or* $_{2b}$✓

correct read off at 1.60 mm, leading to answer in range 58 to 64 (kg mm^{-2}) $_{2a}$✓

$_{2a}$✓ *2 or 3 sf values only*

OR

use of use of $B = \frac{their\ F}{\pi \times g \times 10 \times 1.6}$ $_{1b}$✓

$_{1b}$✓ *Condone use of D and h in metres if also seen (and penalised) in* ***part (a)***

consistent calculation of B $_{2b}$✓

$_{2b}$✓ *2 or 3 sf values only*

$_{2b}$✓ *Their B should be* $\frac{their\ F}{493}$

2

[3]

Q5.

(a) use of $\rho = \frac{m}{V}$ **AND** $V = Al$ 1✓

260 (m) 2✓

1✓ Expect to see $V = 2.5\ m^3$ or total $V = 5.0\ m^3$

2

(b) calculates total tension of 3.2×10^6 N 1✓

$F = T - W$ seen **OR** subtracts a weight from tension 2✓

uses $F = ma$ 3✓

0.28 or 0.29 (m s^{-2}) 4✓

Expected values seen:
Total mass = 3.17×10^5 kg
Load weight = 2.75×10^6 N
Cable weight = 3.63×10^5 N
Total weight = 3.11×10^6 N
Resultant force = 9.02×10^4 N

4✓ Calculator values are: 0.28464 (using g = 9.81) and 0.29464 (using g = 9.8)

4

[6]

Q6.

(a) $n = 43.1$ ✓ (≥ 2 SF)

$$n = \frac{105 \times 10^3 \times 1}{8.31 \times (273 + 20.0)}$$

1

(b) Use of $m = \frac{\rho V}{nN_A}$ OR $m = \rho V$
OR use of $m_{\text{molecule}} = \frac{m_{\text{gas}}}{N_A}$ OR $N = nN_A$
OR $(c_{\text{rms}})^2 = \frac{3p}{\rho}$ seen in any form
OR use of their mass with $pV = \frac{1}{3}Nm(c_{\text{rms}})^2$
OR use of $\frac{1}{2}m(c_{\text{rms}})^2 = \frac{3}{2}kT$ ✓1
Correct answer see table ✓2

Correct SF see table ✓3

n	✓2 c_{rms}/m s^{-1}	✓3 SF
Without *n*	500-503	3 SF (501-503)
n more than 3SF	500-503	3 SF (501-503)
43.1	500-503	3 SF (501-503)
43	500-503	2 SF (500)
40 (no evidence of *n* = 43 in **part (a)**)	482-484 or 500	2 or 1 SF (480 or 500)
40 (evidence of *n* = 43 in part **part (a)**)	482-484 or 500	1 SF (500)

*Allow ecf for incorrect T and/or n in part **(a)***

Several approaches are possible

$$m = \frac{pV}{nN_A} = \frac{1.25\times1.00}{43.1\times6.02\times10^{23}} = 4.82\times10^{-26}$$

(5.1 × 10^{-26} if 40 used)

$$c_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3\times1.38\times10^{-23}\times293}{4.82\times10^{-26}}} = 502$$

OR

$$pV = \frac{1}{3}Nm(c_{rms})^2 \qquad p\frac{Nm}{\rho} = \frac{1}{3}Nm(c_{rms})^2$$

$$(c_{rms})^2 = \frac{3p}{\rho}\left(=\frac{3pV}{Nm} = \frac{3p\times1}{\rho}\right)$$

$$c_{rms} = \sqrt{\frac{3\times105\times10^3}{1.25}} = 502$$

3

(c) T = 4 × 293 or 4 times the starting temperature in K ✓

change in temperature = 879 (K) ✓ (correct answer gains both marks)

Alternative

$T = \frac{m(2c_{rms})^2}{3k}$ correctly calculated for their m, c_{rms} ✓

Their calculated T - 293 ✓ 7709

mp1 Using $\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT$ so $(c_{rms})^2 \propto T$

$\frac{(c_{rms})^2}{293} = \frac{(2 \times c_{rms})^2}{T}$

T = 293 × 4 = 1172 K

mp2 change in temperature = 1172 - 293 = 879 K

Allow answer that rounds to 880 (K)

If no other marks awarded award max 1 when T is 4 times original and Δθ = 60

2

(d) Max 2 from: ✓✓

- Calculation of mass of water condensed in one hour 1.25 × 960 × (0.0057 - 0.0037) = 2.4 (kg)
- use of their mass with $mc\Delta\theta$ (expect 4.5×10^4 (J))
- use of their mass with mL (expect $5.5(2) \times 10^6$ (J))

heat energy removed = 5.6×10^6 (J) ✓

3

[9]

Q7.

(a) Max 2 ✓✓

- $\omega = \frac{2\pi}{T} = \frac{2\pi}{27.3\times24\times60\times60} = 2.664\times10^{-6}\ (\text{rad s}^{-1})$
  or $v = \frac{2\pi r}{T} = \frac{2\pi\times4.489\times10^{8}}{27.3\times24\times60\times60} = 1196\ (\text{m s}^{-1})$
  Substitution or value
- Idea (resultant) gravitational field strength is equal to centripetal acceleration e.g.
  $g_R = a$ or $g_R = r\omega^2$ or $g_R = \frac{v^2}{r}$ ($= 3.19\times10^{-3}$ m s^{-2})
- Idea that $g_M = g_R - g_E$

MP1 may be part of MP2

Ignore PoT, rounding errors and minor copy errors for MP1 and MP2

A substitution into $T^2 = \frac{4\pi^2 r^3}{GM}$ *or equivalent is not accepted for the first bullet.*

In the second bullet point do not allow g_m

MP3 must follow from correct working

1.21×10^{-3} ≥ 3 SF from correct working ✓ (N kg^{-1})

3

(b)

$$r = \sqrt{\frac{GM}{g_M}} = \sqrt{\frac{6.67\times10^{-11}\times7.35\times10^{22}}{1.21\times10^{-3}}}\ ✓$$

*Allow ecf from **part (a)***

6.37×10^{7} (m) ✓

Allow 6.38×10^{7} *or* 6.39×10^{7} *or* 6.4×10^{7} *(m)*

2

[5]

Q8.

(a) Determination of focal length of objective

OR adds their f_o and f_e ✓

$f_o = M \times f_e = 75 \times 0.022 = 1.65$ (m)

1.67 (m) CAO ✓

No sf penalty

Condone 2 sf 1.7

2

(b) Determination of angle subtended by Jupiter at unaided eye

OR uses:

distance to Jupiter = diameter of Jupiter ÷ angle subtended with their diameter OR their angle ✓

E.g.

$1.7 \times 10^{-2} / 75 = 2.3 \times 10^{-4}$ (rad)

$2 \times 7.0 \times 10^{4}/2.3 \times 10^{-4}$

In MP1 allow use of trig and angle in degrees or radians. Condone use of 1.7×10^{-2} degrees.

distance = 6.2×10^{8} (km) ✓ CAO

Do not award MP1 if both angle and diameter are incorrect.

2

[4]

Q9.

(a) Determines s and r in consistent units

OR

Uses A = 2 × parallax angle = 2 × (1÷$(\frac{79}{3.26})$)

✓

eg for MP1

- *$s = 2 \times 1.5 \times 10^{11}$ m; $r = 79 \times 9.46 \times 10^{15}$ m*
- *$s = 2 \div 2.06 \times 10^{5}$ pc; $r = 79 \div 3.26$ pc*
- *tan (A/2) = orbital radius ÷ distance to star*

with consistent units

$A = 4.0 \times 10^{-7}$ rad $= 2.3 \times 10^{-5}$ degrees

Evidence for MP1 can be seen in the figure.

2.3×10^{-5} degrees CAO ✓

2

(b) Use of $m - M = 5 \log (d/10)$ with two correctly substituted from m, M or d

$_1$✓

If no other mark given, award 1 mark for recognition that 0.40 pc is a lot less than the distance to nearest known star and therefore determination must be incorrect.

For MP2 expect to see

Obtains correct value of m, M or d $_2$✓

d = 2.3 ***pc*** *OR m = 9.7 OR M = 20.5*

Alternative for MP1 and MP2

using m, M and d in $m - M = 5 \log (d/10)$ $_1$✓

seeing -3.2 for LHS and -7.0 for RHS $_2$✓

Compares **their** value with value given in question $_3$✓

MP3 and MP4 cannot be awarded without a comparison of the distances.

Makes comment about significance of difference between **their** values related to the distance AND some idea of whether the astronomer's suggestion is valid consistent with their values.$_4$✓

MP4 is for a recognition of the large difference between their calculated value and value given in question eg by proportion, >>, 6 x bigger, significantly bigger etc.

If a difference is calculated in MP3, for MP4 to be awarded the difference must compared to one of the distances.

4

[6]

Q10.

(a) Use of $\lambda_{max}T$ = constant to determine their λ_{max}, their T or their constant✓

Throughout the answer:

Allow 0.47 to 0.49 μm for λ_{max} from the graph

Comparison with $\lambda_{max} = 0.48 \times 10^{-6}$ (m) OR $T = 6.0(4) \times 10^3$ (K) OR constant = 0.0029 m K
AND conclusion that the graph is consistent.✓

Allow 6.17×10^3 to 5.92×10^3 (K) for their calculated T.

Allow 2.82×10^{-3} to 2.94×10^{-3} (m K) for their calculated constant.

2

(b) Using $P = \sigma A T^4$ to give
$P = 5.67 \times 10^{-8} \times 4\pi \times (9.6 \times 10^6)^2 \times 6000^4$ ✓

*In MP1 condone **one** error from*

- *missing the 4*
- *missing the π*
- *doubling the radius and using it as r in an area calculation*
- *POT errors*

Condone σ for 5.67×10^{-8}

8.5×10^{22} (W) ✓

*Allow full credit for use of their T from **part (a)***

eg $T = 6.04 \times 10^3$ (K) gives 8.75×10^{22} (W)

2

[4]

Q11.

(a) Idea that Hubble's Law is used to estimate the age of the Universe. ✓

Allow determination of H^{-1} or H for the values in the question.

Accept idea that age is related to gradient of graph of v against d.

So no, as Andromeda is approaching / is blue-shifted ✓

Allow ";Hubble's Law is only used with receding/redshifted galaxies."

2

(b) Calculates mass of black hole = $1.60 \times 10^8 \times 1.99 \times 10^{30}$ 1✓

Correct answer gets 1✓2✓

Correct answer with correct unit gets 1✓2✓3✓

Use of

$$R_s = \frac{2 \times 6.67\times10^{-11} \times \textit{their mass of black hole}}{(3\times10^8)^2}$$ 2✓

= 4.7×10^{11} m 3✓

Also accept

4.7×10^8 km

3.1 AU

1.5×10^{-5} pc

5.0×10^{-5} ly

Unit mark is based on correct calculation.

3

[5]

Q12.

(a) MAX 4 from:

- Attempts to find area of large loop
- Subtracts area of small loop
- Shows suitable scaling factor
- Uses 4 cycles s^{-1}
- correctly calculates indicated power using their values.

592 W ✓ (cao)

eg counting small squares
157 - 9 squares = 148 squares
scaling factor of $0.10 \times 10^{-3} \times 0.1 \times 10^5 = 1.0$ J per square
148 J × 1.0 = 148 J
If counting 'large' squares:
(6.5 - 0.5) squares $\times 0.50 \times 10^{-3} \times 0.50 \times 10^5$ gives 150 J
Accept approximating to triangles
cycles s^{-1} = 4 (as it is double acting at 2 rev s^{-1})
indicated power = 148 × 4 = 592 W ± 30 W

5

(b) Input power = $6.44 \times 10^{-4} \times 18.0 \times 10^6 = 11.6 \times 10^3$ W ✓
Output power = $T\omega = 39.0 \times 2 \times 2\pi = 490$ W ✓

Correct answers only
Accept 1.2×10^4 W or 12000W
Condone working not shown provided answers are correct.

2

[7]

Q13.

(a) Either conversion of 1 MeV to J or $W = QV$

$1.60 \times 10^{-19} \times 1.30 \times 10^{6} = 2.08 \times 10^{-13}$ ✓ (J)

At least 2 sf required.

1

(b) $Q = mc\Delta\theta = 1.5 \times 903 \times 68.0$ (= 92 106 J) **OR**

E_K of one electron $= \frac{92\,106}{4.50 \times 10^{17}}$ ✓ $(= 2.05 \times 10^{-13}\text{ J})$

Both calculations and correct conclusion, eg
Yes, this is consistent with an accelerating voltage of 1.30 MV. ✓

Alternative route

Total E_K for all electrons =

$2.08 \times 10^{-13} \times 4.50 \times 10^{17}$ = (93 600 J) ***OR***

$\Delta\theta = \frac{Q}{mc} = \frac{93600}{1.5 \times 903}$ ✓ (= 69.1 K)

which is consistent with the temperature rise observed. ✓

Can also compare total E_K with $mc\Delta\theta$ for MP2.

Use of 2.0×10^{13} gives total E_K of 90 000 J and $\Delta\theta$ of 66 K which is consistent.

Allow comparison of in eV or accelerating pd (1.28×10^{6}) with 1.3×10^{6} V or MeV with MV.

2

(c) Correct calculation of non-relativistic E_K ✓a

Statement or attempted use of $E_K = mc^2 - m_0c^2$ ✓b

Correct calculation of relativistic E_K ✓c

Both calculations and comparison of with 2.1×10^{-13} or 2.0×10^{-13} J to conclusion consistent with idea that student B is correct ✓d

$$E_K = \frac{1}{2}mv^2 = 3.78 \times 10^{-14}\text{ J}$$

$$E = \frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_0c^2 = 2.11 \times 10^{-13}\text{ J}$$

For ✓d allow a comparison of $\Delta\theta$ from

$m_{Al}c\Delta\theta = N(mc^2 - m_0c^2)$ with 68°

Allow ecf for ✓d for minor calculation error, rounding error or transcription errors but there must be a relativistic KE and non-relativistic calculation to award ✓d.

Alternative

Calculation of speed using $v = \sqrt{\frac{2E_k}{m}}$ ✓a

Statement or attempted use of $E_K = mc^2 - m_0c^2$ ✓b

Calculation of speed from relativistic equation ✓c

Both calculations and comparison of results with 2.88 × 10^8 or 3 × 10^8✓d

$v = 6.8 \times 10^8$ m s^{-1} if using 2.08 × 10^{-13}

$v = 2.88 \times 10^8$ m s^{-1} if using 2.08 × 10^{-13}

*Allow calculations based on the total number of electrons and comparison with **part (b)**.*

Alternative for Max 2

Correct calculation of non-relativistic E_K ✓a

Calculation of relativistic mass, total energy or $\sqrt{1 - v^2/c^2}$ or $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ **AND** comment that **relativistic effects are significant (owtte)** so B is correct. ✓bcd

If no other marks awarded max 1 for student B is correct because speed is greater than 3.0 × 10^7 m s^{-1} or v is 96% of c (which is greater than 10%).

4

(d) < 29.8 ns ✓

1

[8]

Q14.

(a) (Use of volume (per sec) =) $\frac{\pi d^2}{4} \times 17.2$ ✓

(Volume per second =) 19.45 (m^3 s^{-1}) = $\frac{774\pi}{125}$

$\frac{\pi d^2}{4} \times 17.2 = \frac{9\pi}{25} \times 17.2$

Use of $\rho = \frac{m}{V}$ ✓

Substitutes their volume (per second) and density where $\frac{m}{t}$ *would be subject. Do not award MP2 if 2 errors are made in substitution.*

(mass per second =) 0.389 (kg s^{-1}) ✓

Answer seen to at least 2 sf.

Calculator display = 0.3890548342

3

(b) Use of $F = \frac{m}{t} \times v$ or (F =) 6.69 N or 6.708 (N) or 6.88 (N)

OR

Use of $W=mg$

OR statement:

Upward force = weight ✓

Possible ECF from ***(a)*** *where their m rounds to 0.4 kg.*

W = 3.72m seen or 3.72m as the subject of a force equation.

Do not allow 3.72 x 0.4 as use of W=mg

.

Applies condition for equilibrium by setting $F = mg$

OR

6.69 = 3.72 m *or* 6.708 = 3.72 m or 6.88 = 3.72 m✓

(m =) 1.80 (kg) ✓

Accept answer correctly rounded to at least 2 sf.

F= 6.88 N where $\frac{m}{t}$ *= 0.4*

m=1.85 kg or 1.8 kg

3

(c) Use of $E = Pt$

OR

converts kWh to J ✓

(E =) 340 × 39 ***or*** *13260 (J)*

(0.035 kWh =) 35 × 3600 ***or*** *126000 (J)*

Alternative MP1 *converts to any of the following units of energy.*

- *0.34 (kW) x 0.0108 (h)* ***or*** *0.00368 (kWh)*
- *0.035 kWh = 35 (Wh)*
- *340(W) ×* $\frac{13}{1200}$ *(h)* ***or*** $\frac{221}{60}$ *(Wh) or 3.683 (Wh)*

Or equivalent e.g W mins

Do not accept incorrect unit.

Do not accept incorrect subject.

MP2

Do not allow answers obtained using incorrect power $(\frac{126000}{39})$

$\frac{340}{incorrect\ power}$ *such as* $\frac{340}{\frac{126000}{39}}$

(=) 11% ✓

Accept answer correctly rounded to at least 2 sf.

Calculator display = 10.5238

2

(d) Incorrect:

- this will increase weight **OR** helicopter must provide a greater lift **OR** (more mass therefore) greater GPE (for same height) **OR** (more mass therefore) greater KE (for same speed) **OR** idea that more energy is required. ✓
- the helicopter must displace more (atmospheric) gas (every second to produce greater lift force) **OR** blades must spin faster✓
- the helicopter must do more work every second (so will transfer stored energy at a greater rate) **OR** the helicopter needs more power to fly✓

OR

Incorrect:

- this will increase weight ✓
- atmosphere is too thin and can't displace sufficient mass of gas per second **OR** blades can't spin **fast enough**✓
- can't get off ground due to insufficient lift force ✓

Do not accept increase in resistive forces or increase in drag for increase in weight.

Must state that it is incorrect for all 3 marks.
Maximum of 2 marks for suggestions that more than doubles flight time.

Accept lift or thrust or upward force.

*A maximum of 1 mark for **MP3** and **MP1** where only mark seen is : idea that more energy is required.*

***MP2** can be scored independent of this.*

3

(e) Use of an appropriate equation of motion:

$v = u + at$ ✓

*By correct substitution including signs **or** correct rearrangement to make t subject.*

(t =) 0.15 (s) ✓

Accept answer correctly rounded to at least 2 sf.
Calculator display = 0.14784946236559

2

(f) Use of $v^2 = u^2 + 2as$

OR

Use of $v = u + at$ **and** $s = ut + \frac{1}{2}at^2$ **ECF**

OR

$mg\Delta h = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ ✓

(h =) 0.61 (m) ✓ **ECF**

***MP1** (Downward journey)*
Allow s = 0.65m
$2.2^2 = 0^2 + 2 \times 3.72 \times s$
OR
$2.2 = 0 + 3.72\,t$ ***and*** $s = 0 + \frac{1}{2}\,3.72\,t^2$ ***ECF***
OR
$m \times 3.72\,\Delta h = \frac{1}{2}\,m2.2^2$
MP1 (Upward journey)
Allow s=0.041 m obtained from
$s = 0.55 \times 0.15 - \frac{1}{2}\,3.72 \times 0.15^2$ ***ECF***

OR

$0^2 = 0.55^2 - 2 \times 3.72 \times s$

*Check possible **ECF** for t from (e) used in calculation.*

*Condone sign suppression in **MP1** where answer of 0.65 m or 0.041 m or 0.6(1) m is seen.*

Accept answer correctly rounded to at least 2 sf.

Calculator display = 0.60987903225806

2

[15]

Q15.

(a) callipers may **reduce** the (reading of the) diameter ✓

treat ‘change reading’ / ‘give incorrect reading’ as neutral;

accept the idea that the callipers may ‘distort’ / ‘deform’ / ‘push in’ the putty, eg ‘change the shape’ / ‘crush’ / ‘squash’ / ‘cut into’ / ‘squeeze’

reject implication that density could change, eg ‘volume will change’ / ‘will compress’;

reject ‘putty will move’ / ‘not able to grip the putty hard enough’

1

(b) average d

OR

uncertainty in d $_1$✓

percentage uncertainty ≥ 3 sf $_2$✓

answers to >3sf rounding to 2.37(%) earns both marks

for $_1$✓ either average = 33.8(0) (mm) OR uncertainty from half range = 0.8(0) (mm);

allow 1/2 × (34.5−32.9) seen in working;

credit if seen in a percentage uncertainty calculation

1

percentage uncertainty 2.37(%) $_2$✓

for $_2$✓ percentage uncertainty to > 3 sf;

reject decimal answer or incorrect rounding to 2.36%;

reject answers if either 32.9 or 34.5 are (wrongly) rejected as anomalous (leading to 1.62% and 1.64% respectively)

1

(c) % uncertainty in length correct $_1$✓

for $_1$✓ minimum 2sf CAO; 2.8(2)%

1

calculates % uncertainty in volume $_2$✓

for $_2$✓ % uncertainty in V = 2 × their % uncertainty in d + their % uncertainty in L; allow 2.4% for % uncertainty in d

minimum 2 sf; expect 7.6 %

1

evidence for volume evaluated

OR

evidence for Δ volume evaluated ₃✓

for ₃✓ accept answers including:

*sub of **all data** in to* $V = \frac{\pi \times (\text{their}\,d)^2 \times L}{4}$

OR

*sub of **all data** in to*

$\Delta V = \frac{\pi \times (\text{their}\,d)^2 \times L}{4}$ *× their % uncertainty*

/ ΔV = their volume × their % uncertainty

OR

recognisable ΔV with POT error

1

Δ volume between 4.8 and 4.9 × 10^3 (mm^3) ₄✓

answers that round to 4.8 or round to 4.9 are acceptable;

₃₄✓ for Δ volume in range and correct POT

1

(d) ruled line ₁✓

for ₁✓ line passing below 5th AND above 4th ie no overlap between line and either +;

line passing through or extrapolated to (0, 0) to half a minor grid square;

withhold this mark if line is poorly-marked (if doing so annotate clip to explain)

1

gradient calculated ₂✓

for ₂✓ gradient calculated from ΔR divided by ΔL^2;

minimum ΔL^2 = 25 (×10^{-3} m^2);

allow read-off errors in calculation / allow missing or incorrect POT

1

ρ in range 3.72 to 3.84 (× 10^{-2}) ₃✓

for ₃✓ accept 2 sf 3.8

1

POT and unit correct ₄✓

for ₄✓ treat 3.78 × 10^{-2} and 0.0378 Ω m as equally acceptable;

allow alternative valid answer, eg 37.8 Ω mm

1

[11]