Mark schemes

1. (a) MAX 2

Uncertainty in one/each <u>reading</u> is 1 mm $_1$✓

Allow the uncertainty in (reading) the position of a spot is 1 mm. $_1$✓

OR
The measurement involves making two readings / there are two uncertainties (to be considered) in this measurement $_1$✓

Owtte

Difficulty / uncertainty in locating (exact) position of (centre of) spot $_2$✓

Or
Difficulty / uncertainty in lining up the (centre of the) spot with a graduation on the ruler $_2$✓

Or
Difficulty / uncertainty in locating the position of A / B $_2$✓

Do not allow:

- *because the smallest division is 1 mm*
- *hard to see measurements to less than 1 mm (need to link to position of spot (or A or B)*
- *"because of both sides of the ruler" on its own*
- *"ruler slightly misaligned" too vague*

the uncertainties from two (readings) are added $_3$✓

insufficient includes:

- *uncertainty doubles*
- *uncertainty is twice the smallest division*
- *Random error or human error or error without further detail.*

However:

The uncertainty doubles because there are two readings scores MP1

Also:

The uncertainty doubles because there are two readings <u>with identical uncertainties</u> would score 2 marks.

Mention of range of repeated measurements ÷ 2 is not applicable in this case.

2

(b) (Adds the uncertainties =) 4 (mm) $_1$✓

Or
Use of by substitution

(percentage uncertainty=) $\frac{\text{uncertainty}}{\text{value}}$ (×100) (%) $_1$✓

(% uncertainty =) 0.74 **or** 0.7 (c.a.o) $_2$✓ (**1 or 2 significant figures only**)

1st mark

Expect to see:

(percentage uncertainty=) $\frac{4}{544}$ *(×100) (%)*

Maximum 1 mark for

Condone (in substitution):

- *2/289, 2/255, 2/272, 2/544, 4/289, 4/255, 4/272*
- *power of ten errors (POT errors)*
- *must be a recognisable uncertainty*

Maximum 1 mark for

use of

(percentage uncertainty=) $\frac{\text{uncertainty}}{\text{mean (value)}}$ *(value)(×100) (%)*

along with substitutions of

- *2/289, 2/255, 2/272, 2/544, 4/289, 4/255, 4/272, 4/544*
- *power of ten errors*

condone for 1 mark

((2/289 + 2/255) × 100 =)

1.48% or 1.5%

2nd mark

Condone working leading to 2nd mark for:

Use of (percentage uncertainty=) $\frac{2}{272}$

Do not allow mean of two separate % uncertainties ***or*** *incorrect formula quoted and used in workings*

2

(c) MAX 2

The percentage uncertainty in c is smaller than for a or b because c has a larger value (than a or b separately)$_1$✓

or % uncertainty in c is half the percentage uncertainty in a + b $_1$✓

or The percentage uncertainty in c is smaller because its uncertainty is smaller for the same data value $_1$✓

Insufficient:

- *c has a smaller uncertainty*
- *a + b has a larger uncertainty*
- *The uncertainty of a + b is combined*

c's (% uncertainty =) 0.37 or 0.4 $_2$✓ or c's (% uncertainty =) $\frac{2}{544}$ × 100 $_2$✓

idea that c's measurement involves fewer readings than the sum of a and b $_3$✓
or
idea that c requires fewer measurements than the sum of a and b $_3$✓

Accept converse

Where numbers are quoted, these must be consistent with terms used.

4 readings, 2 readings

2 measurements, 1 measurement

2

(d) (when laser is switched on) always stand behind the laser (unless taking readings) ✓

Or
if in front of laser (when switched on) look away from the laser (eg when taking readings) ✓

Or
if in front of laser (when switched on) don't look at/towards the laser (eg when taking readings) ✓

Or
don't look directly into the laser (beam) ✓

Or
direct laser towards nearest wall ✓

Or
switch off laser when not in use ✓

Or
ensure (glass) reflective surfaces are covered (prevent reflections) ✓

Or
Do not shine the laser onto a reflective surface ✓

Or
place safety notices outside the laboratory [room] ✓

Or
don't shine laser at eye level ✓

Or
mark positions with pen/pencil and measure after laser switched off ✓

Or
laboratory is normally illuminated (not darkened) ✓

Where a list of safety measures has been given:

- *Treat more than one correct as neutral*
- *Penalise incorrect safety measure in a list that may include correct safety measures.*

Do not credit weak statements:

- *Do not look at the laser*
- *Don't point the laser anywhere except at the grating*
- *Don't look directly at the laser*

Beware of references to "the light".

1

(e) (tan $\theta = \frac{0.544}{1.280}$ = θ =) 23.0(°) ✓

allow 2 or more significant figure answer

acceptable common answers:

23, 23.0, 23.03, 23.025, 23.0255

Where more than 3 sf quoted, the number must be correct.

alternative method

*(valid attempt to determine distance from grating to spot **E**, eg*

(distance = $(\sqrt{0.544^2 + 1.280^2})$ *= 1.391)*

(sin $\theta = \frac{0.544}{1.391}$ *= 0.391)*

(θ =) 23.0(°) ✓

allow 2 or more significant figure answer

acceptable common answers:

23, 23.0, 23.03, 23.025, 23.0255

Condone mid-calculation rounding leading to errors in 4th sf where quoted.

1

(f) use of $n\lambda = d\sin\theta$ $_1$✓

or

(if nothing else seen) d = 3.3 × 10^{-6}m $_1$✓

Use of:

Correct rearrangement where subject would be λ

or correct substitution of n, d and θ

Expect to see n = 2 , d = 3.3(3) × 10^{-6} , θ = 23(.0)

*Condone **one** error in substitution for n or d in a correctly rearranged equation where subject would be λ*

(or where answer indicates the correct working for incorrect numbers, d error leads to 5.86 × 10^4)

Condone power of ten errors in working

λ = 6.5(2) × 10^{-7} (m) $_2$✓ ecf

2 or 3 sf only

where 3 sf quoted answer must be in range 651 to 652 nm (or ecf)

Common ecf (sin θ error in 1.5):

Expect to see an answer that rounds to 7.1 × 10^{-7}m to 2 sf

2

(g) The second mark ($_2$✓) is contingent on the award of the first mark ($_1$✓).

Increase distance from grating to screen / increase y $_1$✓

(This will increase distance y (and/or c) therefore) decreasing the percentage uncertainty in y / c / fringe spacing / θ / sin θ $_2$✓

Do not accept:

- *darkened room*
- *use a (vernier) caliper*
- *use a travelling microscope*
- *Repeat*
- *Repeat and average*
- *Computer / data logger / camera*
- *Ruler with smaller divisions*
- *Make the maxima further apart (details on how this is achieved are required)*
- *Increase distance between laser and screen.*

Decreases the <u>percentage</u> uncertainty in y $_2$✓

Or

Use a higher-order spot $_1$✓

(This will increase distance from centre spot to higher-order spot therefore) decreasing the <u>percentage</u> uncertainty in the fringe spacing/θ /sin θ $_2$✓

Condone reference to this distance as c

Or

Measure distance between A and E $_1$✓

(This increases the distance therefore) decreasing the <u>percentage</u> uncertainty in c $_2$✓

No details of determination of c are required.

2

[12]

2. **B**

[1]

3. (a) general procedure

- collect water for a measured time;
- **divide** measured / calculated volume by time to determine rate $_1$✓

__static__ volume should be measured __after timing__, eg

reject 'measure time to fill cylinder' ***or*** $_1$✓ ***= 0***

accept 'find V for different t, plot V against t,

gradient = Q' but not if by continuous flow method

1

names 2 suitable instruments $_2$✓

for time use <u>stopwatch</u> or <u>stop</u>clock;

treat as neutral: 'timer' or 'light gate / data logger'

for volume use <u>measuring cylinder</u> / graduated beaker;

treat as neutral: 'measuring beaker' / 'burette'

OR

for mass use <u>balance</u>; use of $V = \frac{m}{\rho}$ *(any subject)*

condone 'volume of 1 g is 1 cm ^{3}*';*

reject 'weigh'/'weighed'

1

method to reduce uncertainty in volume $_3$✓

read water level at bottom of the meniscus (or wtte or allow sketch);
don't penalise further use of 'beaker' treat as neutral: 'dry cylinder before use'

OR

procedure to avoid systematic error in determining mass, eg tare / reset / zero the balance with empty beaker on pan / find mass of beaker empty and subtract from mass of beaker plus water;

don't penalise further use of 'weigh'/ 'scales' allow 'use balance on a horizontal surface'

method to reduce uncertainty in time $_4$✓

✓*ensure stopwatch is zeroed / reset before use*

added detail $_5$✓ $_6$✓ $_7$✓

collect large(r) volume / for long(er) time / ≥ 60 s $_5$✓

this reduces percentage / fractional uncertainty $_6$✓

read at eye level or wtte, to reduce parallax $_7$✓

MAX 2

(b) sensible mark identifying second box indicating (N m^{-2} s) only

auto marked question

1

(c) 19.8% (from 4 × 2.9% + 1.8% + 6.4%) earns both marks ✓✓

don't insist on seeing '%' unless 0.198 etc

allow final answer rounded to 20%

allow 1 mark for 0.198 or 0.20 but reject 1 sf 0.2

for incorrect answer the following can earn one mark:

(percentage uncertainty in d =) 4 × 2.9% / 11.6% / 12% seen in working but wrong final answer

OR missing × 4 eg 2.9% + 1.8% + 6.4% = 11(.1)%

OR incorrect multiplier applied to 2.9 eg 2 × 2.9%

OR with × 4 applied wrongly eg

2.9 + (1.8 × 4) + 6.4 = 16.5 % or 17 % /

2.9 + 1.8 + (6.4 × 4) = 30(.3) %

2

(d) appropriate use (ie close to and parallel with the vertical side of the tube, but not necessarily in contact with the tube) of:

a metre ruler made vertical using a set-square in contact with the bench / floor / (flat) surface

OR

a plumb line / weight on vertical string (reject 'pendulum')

OR

a spirit level ✓

the mark can be awarded for a convincing sketch, eg use of a very large set square without ruler

accept 'tri-square' for set square

the only acceptable horizontal reference is the bench: don't allow use of horizontal T, eg set square placed on T even if sketch looks convincing

no credit for attempt to show graduations on tube are horizontal / use of 'protractor' for set-square / 'each side of meniscus at same level' / use of clamp stand rod or wall as vertical reference

1

(e) attempted use of $y = y_0 e^{-\lambda\Delta t}$ with substitution of values of y, y_0 and Δt obtained **directly** from **Figure 4** / plausible values obtained from **Figure 7**

OR

tangent drawn on **Figure 4** to find $\frac{dy}{dt}$;

use of $\frac{dy}{dt}$ = (–) $\lambda \times y^*$ and y^* is where tangent meets the curve $_1$✓

valid calculation **seen** leading to a result for λ that rounds to 3 sf in range 4.45 to 4.55 × 10^{-3} (s^{-1});

award if seen in body of answer $_2$✓

for $_1$✓ do not penalise y / y_0 interchanged, read off errors, manipulation errors / $\Delta t = t / t0 / \frac{t}{t_0}$ or use of incorrect symbols eg A, N for y;

no ecf for $_2$✓

*allow use of **Figure 7***

$y_0 = 60.0$ cm, $y = 52.2$ cm; $\Delta t = 60 - 29 = 31$ s

$52.2 = 60\,e^{-31\lambda}$; $\therefore \lambda = 4.49 \times 10^{-3}\ s^{-1}$

if the intermediate step is seen, eg

$$\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right) = \frac{1}{31} \times \ln\left(\frac{60}{52.2}\right)$$

accept 'log' for 'ln'

no credit allowed for reverse-working method in a 'Show that' problem

no credit for assuming straight line and y = mx + c, measuring the gradient then by determining the equation of the line or by using $m = \frac{y_2 - y_1}{t_2 - t_1}$

determines the half life; finds λ from $\frac{\ln 2}{\text{half life}}$

no credit for common error λ = gradient × 2

for $_2$✓ look for any answer in the body that deserves credit (for a 'Show that' we can overlook truncation in the value given on the answer line)

variation on use of use of $y = y_0\,e^{-\lambda\Delta t}$ for $_1$✓:

λ can be found if points t_1, y_1 and t_2, y_2 are used and the values substituted into $\frac{y_1}{e^{-\lambda t_1}} = \frac{y_2}{e^{-\lambda t_2}}$;

if this approach is used substitute the data into $\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right)$ to confirm that the result for λ is correct before awarding $_2$✓

1
1

(f) use of $T_{1/2} = \frac{\ln 2}{\lambda}$ OR $\frac{\ln 0.5}{-\lambda}$ with substitution of **recognisable** λ;

evaluated to ≥ 2 sf in range 140 s to 170 s ✓

calculation can have any subject;

accept use of 2 sf $\lambda = 4.5 \times 10^{-3}$ usually leading to 154 but allow correctly truncated to 150 or 1.5×10^2

1

(g) (mostly) continuous line drawn on **Figure 7**;

below dashed line and with negative gradient between *t* = 0 and *t* = 120;

do not penalise linear line or shaky / thick / hairy line or slight

discontinuities; accept ≈ horizontal after 100 s 1✓

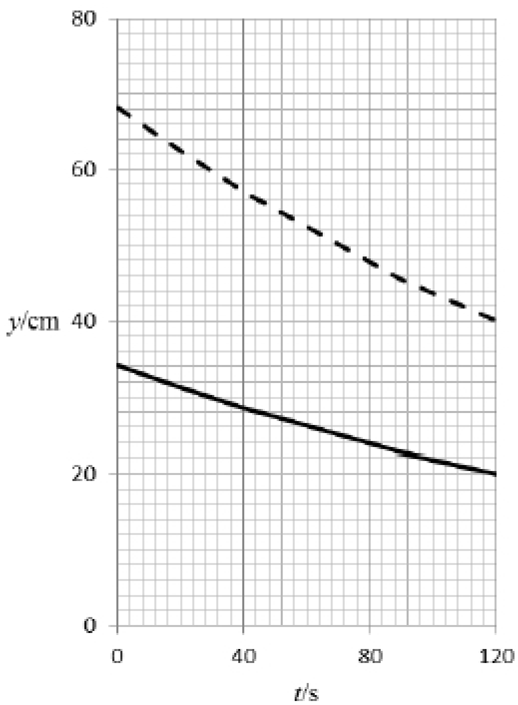
line passes through:

t/s	*y*/cm min	*y*/cm max
0	33	35

AND through EITHER of

t/s	*y*/cm min	*y*/cm max
60	24	28
120	17	23

2✓



2

[13]

4. **B**

[1]

5. (a) to reduce the impact of systematic error: tare [zero] the callipers before use

OR

take reading with callipers fully closed (at some stage) and subtract from readings $_1$✓

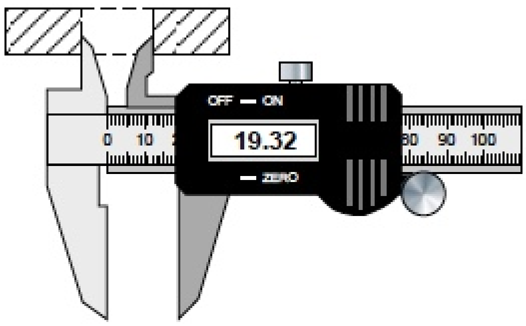
to reduce the impact of random error: take measurement several times for different diameters/directions and calculate mean

OR

take measurement several times for different diameters to check for anomalies $_2$✓

2

(b) use of inside jaws on callipers required: must have a clear drawing with inside jaws in <u>contact</u> internal diameter$_1$✓



*A **sectional** view of the magnet must be given*

Jaws must be inside cavity (as here)

1

(c) Determines a cross-sectional area: (larger A=) 2.82

× 10^{-3} or (smaller area =) 2.932 × 10^{-4}

OR

states that the cross sectional area from Δ

$$A=\left(\frac{\pi D^2}{4}-\frac{\pi d^2}{4}\right)$$

OR

Calculates one volume correctly $_1$✓

Allow POT error $_1$✓ and $_2$✓

Where r is used must have an additional statement on how r relates to D (in the case where there is no correct substitution and no correct answer)

substitution of D = 59.90, d = 19.32 and t = 12.09 into

$$V=\left(\frac{\pi D^2}{4}-\frac{\pi d^2}{4}\right)\times t$$

OR

V = their ΔA × 12.09

OR

Correctly finds difference in ***their*** volumes $_2$✓

Or equivalent

Correct substitution into

$$V = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right) \times t$$

receives the first two marks (allow POT)

Expect values:

V_D *= 3.41 × 10^{-5} (m^3)*

V_d *= 3.54 × 10^{-6} (m^3)*

3.1 × 10^{-5} / 3.05 × 10^{-5} / 3.053 × 10^{-5} (m^3) $_3$✓

no limit on maximum sf

Correct answer scores 3

Allow 3rd sf round error where

answer rounds to 3.1 × 10^{-5}

when correct method seen

3

(d) ***Procedure:***

MAX 2

Take more measurement(s) of *h* for additional / different masses (of clay) ✓

More than one added mass, allow varies amount of clay

Convert (total) mass into weight (and equal to the repulsive force of magnet **A** on magnet **B**) ✓

Describe method to measure *h* using ruler or set square ✓

(in this case determination of k must be consistent with graph)

Analysis:

Plot a graph of *F* against $1/h^3$ ✓

Condone $1/h^3$ *against F or equivalent*

Should be a straight line of best fit ✓

This mark can be awarded if seen by drawing of straight line with positive gradient on sketch of graph

***Determination of k*:**

MAX 1

Measure gradient and set equal to *k* ✓

Allow one mark for plot of F against h^3 *and statement that area under graph is k. Mark* ***Procedure*** *as scheme*

Substitute (total) weight into formula and rearrange to find *k* ✓

Must be consistent with graph

5

[11]

6. (a) path difference for two waves ✓

Allow 'waves travel different distances'

Condone out of phase

gives rise to a phase difference ✓

if phase and path confused only give 1 for first 2 marks

Destructive interference occurs ✓

allow explanation of interference

3

(b) (Path difference =) 0.056 m ✓

Path difference = 2λ or wavelength = 0.028 m ✓e

Use of $f=c/\lambda$ so f = 11(10.7) × 10^9 Hz ✓

Allow 2 max for 5.4 × 10^9 Hz or 2.7 × 10^9 Hz

Allow ecf

3

(c) Intensity decreases with distance ✓

One wave travels further than the other ✓

Amplitudes/intensities of the waves at the minimum points are not equal ✓

Or "do not cancel out"

max 2

(d) The signal decreases/becomes zero ✓

The waves transmitted are polarised ✓

zero when detector at 90° to the transmitting aerial/direction of polarisation of wave ✓

max 3

[11]

7. (a) Both t_m values correct: 0.404, 0.429
AND
Both t_m^2 values correct: 0.163, 0.184 ✓

Exact values required for the mark.

1

(b) Both plotted points to nearest mm ✓
Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line.

2

(c) Large triangle drawn (at least 8 cm × 8 cm) ✓
Correct values read from graph ✓
Gradient value in range 0.190 to 0.222 ✓

Allow 2 or 3 sf for gradient

3

(d) g = 9.71 (ms^{-2}) or correct value from gradient value in **(c)** ✓.

(The answer must be in the range 9.0 to 10.5 (ms^{-2})).

Allow 2 or 3 sf.

Unit not required

1

(e) $\% \; difference = \frac{(9.81 - 9.71)}{9.81} \times 100 = 1.02$

OR correct computation using value from **(d)** ✓

If the candidate's value is exactly 9.81, then a statement that there is no (or zero) percentage difference is acceptable.

No sf penalty.

NB. Allow an answer from a calculation with either the candidate's value or the accepted value as the denominator in the equation.

1

(f) 0.001 s✓ (half the spread)
(Must have unit).

1

(g) $g = 2s/t_m^2$ ✓
$= 2 \times 0.300/0.245^2$ ✓
$= 10.0$ (or 10.00) ms^{-2} ✓

Unit required and 3 or 4sf for the last mark.

3

(h) % uncertainty in s = 0.33 **and**
% uncertainty in t_m = 0.41 ✓

Allow ecf from part ***(f)****.*

% uncertainty in g
= 0.33 + (2 × 0.41) = 1.15 ✓

Allow ecf at each stage of calculation.

Uncertainty in g
= 10.0 × 1.15/100 = 0.12 m s^{-2} or 0.1 m s^{-2} ✓

Allow ecf from part ***(g)****.*

(allow 1 or 2 sf only)
(Must have unit for 3rd mark).

3

(i) (a) Use spherical objects of different mass **and** determine mass with balance ✓

Annotate the script with the appropriate letter at the point where the mark has been achieved.

(b) Would need **same diameter** spherical objects for fair comparison (same air resistance etc) ✓

(c) Time spherical object falling through same height **and** compare times

*Alternative for **(c)**:*
i.e. repeat whole of experiment, plot extracted values of g against mass. Horizontal line expected, concluding acceleration same for different masses.

3

[18]