**M1.A**

**(1)**

**M2.** (a) circuit diagram to show:
ammeter in series, voltmeter in parallel **(1)**variable source (e.g. battery + rheostat or potential divider) **(1)**

**(2)**

(b) (i) *R*X *=* = 56 Ω **(1)**

(ii) *R*X = (e.g.) = 23 (Ω) **(1)**

*R*X depends on current (or voltage) non-ohmic

**(3)**

(c) (i)

|  |  |
| --- | --- |
| col C | col D |
| 0.15 | 2.53 |
| 0.20 | 2.83 |
| 0.25 | 3.09 |
| 0.30 | 3.37 |
| 0.35 | 3.66 |
| 0.40 | 3.94 |

four pairs of values correct **(1)**all six pairs correct and col D to no more than 4 s.f **(1)**

(ii) axes labelled **(1)**suitable scales chosen **(1)**at least five points plotted correctly **(1)**acceptable straight line **(1)**

(iii) *k* = gradient **(1)**

gradient = = 5.7 (V–1) **(1)**

intercept on *y*-axis =ln *A* **(1)**

(intercept = 1.68 gives) *A* *=* e1.68 = 5.4 (mA) **(1)**

unit for *k* or *A* correct **(1)**

(iv) the points define a straight line **(1)**valid over given range **(1)**

**Max 10**

**[Total 15]**

**M3.**(a) (i) percentage uncertainty in meter deflection = 1/32 × 100 = 3%

uncertainty in *d* = 1 / 152 × 100 = 0.7%

**(2)**

(ii) calculates *V* / *d*3 correctly for 2 sets of data

calculates this correctly for all sets of data

states conclusion

**(3)**

(b) resistance of coil = 1.5 / 0.45 = 3.3 Ω

length of wire = *nπd* = 44 m

resistivity = 5.0 × 10–8 Ω m (c.a.o.)

**3)**

(c) increase turns on 5000 turn coil
**or**
increase turns on 200 turn coil **and** increase the supply voltage
**or**
increase the supply voltage / current

this will increase the voltage measured by increasing the rate of change of flux

repeat observations and average

this reduces the uncertainty in the readings

make more measurements at more frequent d intervals

to improve confidence and the limits over which the hypothesis is correct

**(Max 4)**

**any two changes with corresponding justification**

the use of Physics terms is accurate, the answer is fluent / well argued with few errors in spelling, punctuation and grammar

**(2)**

the use of Physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor

**(1)**

the use of Physics terms is inaccurate, the answer is disjointed, with significant errors in spelling, punctuation and grammar

**(0)**

**(Max 2)**

**[Total 14]**

**M4.** (a) (i) force per unit mass (allow equation with defined terms)

**(1)**

(ii) diagram of method that will work

(pendulum / light gates / solenoid and mechanical gate / strobe photography / video)

pair of measurements (eg length of pendulum and (periodic) time / distance and time of fall – could be shown on diagram)

instruments to measure named quantities (may be on diagram)

correct procedure (eg calculate period for range of lengths, measure the time of fall for range of heights)

good practice – series of values and averages / use of gradient of graph

appropriate formula and how *g* calculated

**(6)**

(b) (i) evidence of *gr*2 being used

values of 0.25, 0.11, 0.06(25)

no s.f. penalty here unless values given as fractions

**(2)**

(ii) points correctly plotted on grid (e.c.f.)

smooth curve of high quality at least to 10 × 107 m, no intercept on *r* axis

**(2)**

(iii) attempt to use area under curve

evidence of × 800 kg

(4.3 – 5.3) × 109 J

**or**

use of equation for potential Δ*EG* = *m*(*g*1*r*1 – *g*2*r*2)

evidence of × 800 kg

(4.7 – 4.9) × 109 J

max 2 if assumed values of *G* and *M* used

allow calculation of *GM* from graph followed by substitution into Δ*EG* = *MG*(*m* / *r*1 – *m* / *r*2) for 3 marks

**(3)**

**[Total 14]**

**M5.** (a) curve drawn of approximately correct general shape

curve shows inverse square law e.g.

includes the point (3.0 , 12.5) **or** (1.5, 50) **or** (2.0, 28.1)

**(2)**

(b) (i) measure and deduct background count (rate)

**(1)**

(ii) count for large periods (to ensure large N)

**or** repeat counts and average

**(1)**

**[Total 4]**

**M6.** (a) (i) *Z* increases by 1

*A* remains the same

**(2)**

(ii) Correct curvature starting at 120 Bq

60 (or 0.5 × their start value) at 12 h days later

30 (or half their value at 12 h) and continuing to fall thereafter approximately exponentially**(3)**

(b) (i) 6.6 × 10–11 J (s–1)    (120 × 5.5 × 10–13)

**(1)**

(ii) another particle is emitted in each decay (not gamma radiation)
**or**
the nucleus recoils

anti-neutrino emitted (this would get first and second
mark 2 marks)

the other particle/neutrino/antineutrino/nucleus takes
some/varying amounts of the energy

**(3)**

(c) 7.5 × 106

**(1)**

(d) Particles are emitted in all directions/particles do not all go to detector

Detector only detects some of the particles **that enter it**/mention of dead time or recovery time
(**not** detector does not detect all the particles - this adds nothing)

Some particles are absorbed by the window

**Max (2)**

**[Total 12]**

**M7.** (a) all plots correct to ½ small square
*deduct 1 mark for one incorrect, 2 marks for 2+ incorrect*

line appropriate

**(3)**

(b) one correct determination from correct numbers

154 ± 10 s

two correct determinations and average

**(3)**

(c) (use of *A =* λ*N*) 480 = λ × 1.1 × 10–5

*[allow λ = ln 2/t ½ ]*

4.4 × 10–3 s–1 [4.36]

**(2)**

**[Total 8]**

**M9.*planning***

(a) sensible key factor e.g. p.d. across paper, that, when varied, leads to the determination of resistance: candidate then goes on to estimate the thickness of the paint layer on strip [only allow direct measurement of resistance if the investigation is of how either width or length of a rectangular strip affects the resistance of the paper] **(1)**

(b) correct measuring instrument given [allow circuit diagram] **(1)**

(c) dimensions of paper constant when resistance measured [to see how a certain dimension influences the resistance, width (if length varied)/length (if width varied)] **(1)**

(d) check that current through paper does not exceed 200 mA **(1)**

(e) sensible qualitative prediction given: thickness can only be estimated due to uncertainty in resistivity **(1)**

(f) thickness of layer (assuming uniform coating) in range 10–7 to 10–11 m **(1)**

[or if (e) is a sensible qualitative prediction given: *R* ∝ *l* or *R* ∝ *w*–1]

(g) reasonable physics reasoning given in support: similarity with behaviour of a metallic conductor **(1)**

(h) use of *VlI* to find *R* (use of repeated readings to reduce uncertainty in measurement of dimension) **(1)**

(i) calculating possible range of thickness using limiting values of resistivity / assessing the uncertainty in result [plotting graph of results to check relationship] **(1)**

(j) any other sensible measure, e.g. maintain steady temperature **(1)**

**Max [8]**

**M10.** (a) time for half of (active) nuclei (of radioactive substance) to decay **(1)**

**(1)**

(b)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *t* / minute | 0 | 10 | 20 | 30 | 40 | 50 | 60 |
| number of counts in 30s, *C* | 60 | 42 | 35 | 23 | 18 | 14 | 10 |
| ln *C* | 4.094 | 3.738 | 3.555 | 3.135 | 2.890 | 2.639 | 2.303 |

Correct values of ln *C* above **(1)**

**(1)**

(c) (i) seven points correctly plotted **(1) (1)** [six points correct **(1)**]



(ii) best straight line through points **(1)**

sensible scale **(1)**

(iii) from sensible triangle on graph **(1)**

gradient = – **(1)** 0.030 [0.294] **(1)** (min–1)

**Max (5)**

(d) (i) *C* = *C*0*e*–*λt*, ln *C* – ln *C*0 = –*λt*hence using *y* = *mx* + *c*, *λ* = (–)gradient **(1)**

(ii) half-life = **(1)** = 23 min **(1)**

**(3)**

(e) count over longer period than half minute [or repeat experiment] **(1)**

use stronger source **(1)**

use background count correctly**(1)**

**Max (2)**

(f) for 14C, *λ* = = 1.21 × 104 (year) **(1)**

****

*t* = = 1840 (year) **(1)**

**(4)**

**[Total 16]**

**M11.** (a) *V*0 = 8.0 V **(1)**

(b) *V*rms = 8/√2 = 5.7 (V) **(1)**(allow e.c.f. from (a))

(c) *T* = 3.0 ms **(1)**

(d) *f* = = 330 (333) Hz **(1)**

(allow e.c.f. from (c))

**[Total 4]**

**M12. *planning***

(to determine the illumination at points along axis of the lamp)

measure distance from LDR to lamp using metre rule / tape **(1)**

find resistance of LDR using ohmmeter [or *VI* method explained,

or potential divider method explained: must be from diagram] **(1)**

read illumination from (calibration) graph **(1)**

 (light meter method, scores 2 / 3; single circuit method or interchanged meters, scores 1 / 3)

*diagram*:

sensible diagram to include lamp, LDR (light meter) and suitable means of resistance measurement: symbols must be correct **(1)**

distance, *d*, shown or means to measure it**(1)**

check for correct prediction by repeating at different distances **(1)**

plot a suitable graph to test prediction of **either** student, with method of testing relationship explained **(1)**

(repeated calculations of *L / d*2 and check for consistency is acceptable)

possible approaches for student A to test inverse-square variation:

      

possible approaches for student B to test exponential variation:

      

*control*:

eliminate stray illumination by using blackout [or by collimating beam]

(subtracting background illumination not acceptable)

[or maintain intensity of spotlight by use of appropriate circuit] **(1)**

*difficulties*:

any two of the following: (look for *difficulty + how to overcome* = 2)

reduce uncertainty in the graph **(1)**

by taking extra readings where the illumination changes most rapidly with distance **(1)**

reduce uncertainty in *R* (*V* and *I*) **(1)**

by taking extra readings and averaging **(1)**

overcome uncertainty in *d* **(1)**

by measuring from specified point on lamp **(1)**

[ensure that the LDR only moves along axis of the lamp]

[allow any other good relevant physics]

**(4)**

**[Total Max 8]**

**M13.** (a) (i) the lines are not straight (owtte) **(1)**

(ii) there is no permanent extension **(1)**(**or** the overall/final extension is zero **or** the unloading curve returns to zero extension)

(iii) (area represents) **work done** (on or energy transfer to the rubber cord)
or **energy** (stored) **(1)** not heat/thermal energy

**(3)**

(b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

|  |  |  |
| --- | --- | --- |
| **QWC** | **descriptor** | **mark range** |
| good-excellent | The candidate provides a comprehensive and coherent description which includes nearly all the necessary procedures and measurements in a logical order. The descriptions should show awareness of how to apply a variable force. They should know that measurements are to be made as the force is increased then **as it is decreased**. In addition, they should know how to calculate/measure the extension of the cord. **At least five different masses/’large number’ of masses are used. Minimum 7 masses to reach 6 marks**. The diagram should be detailed. | **5-6** |

|  |  |  |
| --- | --- | --- |
| modest-adequate | The description should include most of the necessary procedures including **how to apply a variable force** and should include the necessary measurements. They may not have described the procedures in a logical order. They may not appreciate that measurements are also to be made as the cord is unloaded. They should know **that the extension** of the cord must be found and name a **suitable measuring instrument (or seen in diagram – label need not be seen)/how to calculate**. The diagram may lack some detail. | **3-4** |
| poor-limited | The candidate knows that the **extension or cord length** is to be measured for **different forces –** may be apparent from the diagram. They may not appreciate that measurements are also to be made as the cord is unloaded.They may not state how to calculate the extension of the cord. The diagram may not have been drawn. | **1-2** |
| incorrect,inappropriateor noresponse | No answer at all or answer refers to unrelated, incorrect or inappropriate physics. | **0** |

**The explanation expected in a competent answer should include
a coherent selection of the following physics ideas.**

diagram showing rubber cord fixed at one end supporting a weight at the other end or pulled by a force **(1)**

means of applying variable force drawn or described (eg use of standard masses or a newtonmeter) **(1)**

means of measuring cord drawn or described **(1)**

*procedure*

measured force applied ( or known weights used) **(1)**

cord extension measured or calculated **(1)**

repeat for increasing then decreasing length (or force/weight) **(1)**

extension calculated from cord length – initial length **(1)**

**[Total 9]**

**M14.** (a) (i) the emf (of the battery) **(1)**

(ii) the voltage across the battery when current flows
[or terminal voltage or pd supplied to the circuit]

(iii) V = (3 × 0.5) = 1.5 (V) **(1)**current = (1.5/14) = 0.11 A **(1)** (0.107 A)

(iv) ( *=* *V* + *Ir* and emf = 3.5 × 0. 5 = 1.75 (V) gives)

1.75 = 1 .5 *+* 0.1 07*r* **(1)**

r = 2.3 Ω

[or use of  = *I* (*R* + *r*) with *I* = 0. 107 gives *r* = 2.4 Ω

and *I* = 0. 11 gives *r* = 1.9 Ω]

(allow C.E. for value of *I* from (iii))

**(6)**

(b) (i) peak value = 3.5√2 = 4.9 V **(1)**

(ii) oscilloscope screen to show vertical line of height 2.5 divisions above central axis **(1)**and below central axis **(1)**

**(3)**

**[Total 9]**

**M15.** (a) (i) (use of *V*rms = gives) *V*0 = 7.1 = 10 V **(1)**

(ii) *T* = 10 (ms) **(1)**

(use of *f* = gives) *f* = = 100 Hz **(1)**

**(3)**

(b) control 1: time base **(1) (**or time period)

(use of *T* = gives) *T* = = 5 × 10–3 (s) **(1)**

setting = 2.5 ms (div–1) **(1)**

control 2: voltage sensitivity or Y-plate setting (or Y-gain) **(1)**setting = 20 V (div–1) **(1)**

**(5)**

**[Total 8]**

**M16.** (a) (i) *T* = 40(ms) **(1)**

 25 Hz **(1)**

*(allow C.E. for value of T)*

(ii) peak voltage (= 3 × 15) = 45 (V) **(1)**

rms voltage = =32 V **(1)** (31.8 V)

**(4)**

(b) (i) *I*rms = = 59mA **(1)** (58.9mA)

(use of 32 V gives 59(.2) mA)

*(allow C.E. for value of Vrms from (a))*

(ii) *V*rms= 59 × 10–3 × 90 = 5.3(1) V **(1)**

*(allow C.E. for value of Irms from (i)) [or V2 =V.]*

**(2)**

(c) *V*peak = 5.31× = 7.5(1) (V) **(1)**

best choice: 5 V per division **(1)**

*(allow C.E. for incorrect Vrms and for suitable reason)*

reason: others would give too large or too small a trace **(1)**

**(3)**

**[Total 9]**

**M17.** (a number correct for alpha **(1)**

number correct for beta **(1)**

alpha decay first goes via Tl **(1)**

numbers correct for Tl (208, 81) **(1)**

beta decay first goes via Po **(1)**

numbers correct for Po (212, 84) **(1)**

**(6)**

(b) (i) use of GM tube + counter/rate-meter **(1)**

measurement of count rate **(1)**

at range of distances + suitable ruler or tape measure **(1)**

specifies suitable range **(1)**

determines background & corrects **(1)**

safety precaution given **(1)**

graph of count rate or corrected count rate against 1/*d2* **(1)**

**(Max 6)**

(ii) gamma not absorbed **(1)**

spreads uniformly from a point source/spherically symmetrically **(1)**

area over which it spreads is proportional to radius squared **(1)**

alpha and beta are absorbed in addition to spreading out **(1)**

**(Max 3)**

**[15]**

**M18.** (a) (i) use of 1.5 cycles **(1)**

conversion to time eg time for 1.5 cycles = 10 × 1.5 = 15ms **(1)**

calculation of frequency eg frequency = 1 / 0.010 = 100 ± 3Hz **(1)**

(ii) peak voltage = 1.5 × 2 **(1)** = 3.0V **(1)**

(iii) rms voltage = 3.0/√2 **(1)** (ce from (a) (i))

rms voltage = 2.12V **(1)**

**(7)**

(b) vertical line is formed **(1)**

of length equal to twice the peak voltage **(1)**

because trace no longer moves horizontally **or** spot moves **just** up and down **(1)**

**(Max 2)**

**[Total 9]**

**M19.** (i) 10.0 (V) **(1)**

**(1)**

(ii) Vrms = 10.0/√2 = 7.1 (V) **(1)**

**(1)**

(iii) time period = 3 × 2 = 6 (ms) **(1)**

**(1)**

(iv) frequency = 1/0.006 or 1/6 **(1)**

frequency = 167 **(1)** (Hz)

**(2)**

**[Total 5]**

**M20.** (a) nuclear fallout / testing / weapons / nuclear accidents / Chernobyl / nuclear waste / nuclear medicine / X-rays / specific uses of radioactive sources eg medical tracers CT scan etc. / cosmic rays as a result of air travel ✔

(Any source of radiation that an individual may encounter which would not have existed 100 years ago)

*No mark for general answers such as ‘medical’ or Nuclear Power / nuclear plant.*

*If a list is given all must be correct but ignore generalisations such as medical or nuclear power.*

**(1)**

(b) (i) *I*15CCR = 2050 – 40 = 2010 ✔

Use of inverse square law eg *I*CCR90 = *I*CCR15. = 2010 × (0.15 / 0.90)2 = 55.8

I90CR = 55.8 + 40

I90CR = 96 counts min–1 ✔

*regardless of order:*

*1st mark subtraction of background in original data*

*2nd mark is for using inverse square function*

*3rd mark is for the answer*

**(3)**

(ii) (reduce impact of) random error / decrease the (percentage) uncertainty / improve the statistics (because the percentage error is proportional to the inverse square-root of the count) ✔ (owtte)

*The answer must be an uncertainty related statement and not increases reliability / accuracy or increased chance of a reading (although these ideas can accompany a correct answer) Ignore comparisons with the background count.*

**(1)**

(iii) use (sensible) absorber between source and detector ✔

(sensible absorber means it must have a noticeable effect e.g. 1mm of metal / aluminium sheet / 5mm perspex but do not allow metal foil / paper sheets. Also its effect must not be so great that it reduces the gamma rays noticeably)

(These two marks are independent)

β shown by count rate falling when sheet of aluminium absorber is used ✔

**Or** (using the existing apparatus)

Compare the results (at various distances) in air with the expected inverse square law ✔

Below the range of beta law does not work but above range it does. ✔

*2nd mark no mark given if count rate falls to zero as γ is still present*

*(magnetic deflection is not common but if seen.*

*Use of magnetic deflection ✔ correct deflection of beta from the beam ✔)*

*(If a cloud chamber is suggested. Observe the tracks in a cloud chamber ✔ beta tracks have varying lengths or they are curly / not straight ✔*

*(The value of the range of beta is not a marking point so accept 15 – 80 cm if a number is given)*

**(2)**

**[Total 7]**

**M21.** (a) (use of *R* = *ρl*/*A*)

*R* = 4.0 × 10–3 × 0.060 **(1)**/(π × 0.0122) **(1)**

*R* = 0.53 (Ω) **(1)**

2 significant figures **(1)**

**4**

(b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

circuit must include:

voltmeter and ammeter connected correctly **(1)**

power supply with means of varying current **(1)**

**2**

|  |  |  |
| --- | --- | --- |
| **QWC** | **descriptor** | **mark range** |
| good-excellent | (i) Uses accurately appropriate grammar, spelling, punctuation and legibility.(ii) Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing.[may include bullet points and/or formulae or equations]An excellent candidate will have a working circuit diagram with correct description of measurements (including range of results) and processing. An excellent candidate uses a range of results and finds a mean value or uses a graphical method, e.g. *I*-*V* characteristics. They also mention precision e.g. use of vernier callipers. | **5**-**6** |
| modest-adequate | (i) Only a few errors.(ii) Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples.An adequate candidate will have a working circuit and a description with only a few errors, e.g. do not consider precision. They have not taken a range of results and fail to realise that the diameter needs to be measured in several places. | **3**-**4** |
| poor-limited | (i) Several significant errors.(ii) Answer lacking structure, arguments not supported by evidence and contains limited information.Several significant errors, e.g. important measurement missed, incorrect circuit, no awareness of how to calculate resistivity. | **1**-**2** |
| incorrect, inappropriate or no response |  | **0** |

The explanation expected in a good answer should include a coherent account of the procedure and include most of the following points.

• length with a ruler

• thickness/diameter with vernier callipers/micrometer

• measure voltage

• measure current

• calculate resistance

• use of graph, eg *I*-*V* or resistance against length

• use of diameter to calculate cross-sectional area

• mention of precision, eg vernier callipers or full scale readings
for V and I

• flat metal electrodes at each end to improve connection

**(6)**

**[Total 12]**

**M22.** (a) Background radiation ✔
Background count = 20 count/minute unit required ✔

*Ignore any –ve sign for background count
Must be written to 2 sf*

**(2)**

(b) Correct line of best fit ✔

*The line must be a straight line (as instructed), with an approximately equal number of points on either side of the line.*

**(1)**

(c) Triangle drawn with smallest side at least 8 cm ✔ (or 8 grid squares)
correct values read from graph ✔
gradient = – 0.00698 (± 0.00030) min–1 ✔
must have –ve sign and must be to 2 or 3 sf ✔

*Gradient must lie within limits stated. No ecf from incorrectly read values unless it falls within stated limits. No unit penalty.*

**(3)**

(d) Recognises gradient = (–) *λ* **or** uses gradient for value of *λ* = 7.0 (± 0.30) × 10–3 minute–1 ✔
*T*½ = 99 minutes to 2 or 3 sf ✔

*For 1st mark accept evidence that value of gradient has been substituted into correct formula for half life. No penalty for missing –ve sign. Allow ect from incorrect gradient value.
Unit penalty if half life has been calculated in different unit (to minutes stated in question)*

**(2)**

(e) Random ✔

**(1)**

(f) (i) Uncertainty = ( ± ) = ± 21
No sf penalty ✔

*Details of calculation not required. Marks can be awarded for correct numerical answers. Also no penalty for quoting uncertainty or % uncertainty without ‘±’.*

**(1)**

(ii) % uncertainty = ± 4.9% ✔
No sf penalty. (Note that % uncertainty in total count is same as % uncertainty in corresponding count rate.)

*Accept also 4.8% (number achieved keeping all sig figs in calculator)
No penalty for omitting % or ‘±’.
No sf penalty*

**(1)**

(iii) % uncertainty for 84 counts is ± 10.9% ✔
Taking data over larger time period / larger total count will have smaller percentage uncertainty. ✔

*Accept ±11%
No penalty for omission of ± sign. No sf penalty for estimated % uncertainties.*

**(2)**

**[Total 13]**

**M23.** (a) λ [the gradient] = (−) 0.015 or similar ✔

*N*½ from ✔

46.2(1) slides (accept 46 but do not penalise '47 slides needed to halve *V*')✔

[λ = 0.015 or use of ratio ✔

determination of *V*0 = 424(.1) mV; ln(*V*0/2) = 5.36 [5.357] ✔

= 46(.0) slides (accept 46.2, '47 slides needed to halve *V*' etc. ✔]

**(3)**

(b) (i) (student must measure or calculate) thickness of slide, *t*; half-value
thickness = *N*½ × *t* [= result from (a) × *t*] ✔

**(1)**

(ii) procedure: measure the thickness of multiple slides (either singly or in a stack) and calculate average thickness [divide by number of slides]✔ (reject bland 'repeat and average')

[measure the thickness at **different points** on the slide, and **average** by number of readings or measure the thickness of different slides and average]

**(1)**

(iii) procedure: **close** jaws and check reading ( = zero) ['check for **zero error**'] ✔

(reject idea of measuring 'known' dimension and checking reading or that 1 micrometer is 'zeroed'/'set to zero'/'zero calibrated' before use’)

**(1)**

(c) *t* from = 1.19 **mm** (3 sf only) ✔

**(1)**

(d) *n* = = 1.47, no unit

(3 sf preferred but tolerate 4 sf, do not penalise here and in part a for sf) ✔

**(1)**

(e) (i)/(ii) Δ (*R*2 − *R*0) = Δ(*R*2 − *R*1) = 0.08 **mm** ✔

**(1)**

(iii) *P*2 − 0 = % uncertainty in (*R*2 − *R*0) = 100 × = 0.56(0)% [0.6%] and

*P*2 − 1 = % uncertainty in (*R*2 − *R*1) = 100 × = 0.82(4)% [0.8%] ✔

working must be shown; allow ecf from i/ii but only if working is correct

Pn = % uncertainty in *n* = (*P*2 − 0) + (*P*2 − 1 ) = 1.38(4)% (accept 1.4 %) ✔

for ecf from i/ii working in iii must be valid; for AE in iii allow ecf in final calculation

[max and min values calculated, eg *n*min = , *n*max = ;

difference = ½ range (✔) convert to % = 1.38 (± 0.02)% (✔)]

**(2)**

**[Total 11]**

**M24.** (a) 5.31, 6.38 ✔ *Exact answers only (***1)**

(b) Both points correctly plotted to the nearest mm✔
Well drawn straight line of best fit.✔

*The orange LED point (4.80, 1.54) is anomalous. The line should follow the trend of the points (ignoring the anomalous point) with an even scatter of points on either side of the line.*

**(2)**

(c) (i) Triangle drawn with smallest side at least 8 cm in length.✔
Correct readings taken from the line for the triangle. ✔
Gradient in range 0.44 to 0.46 (0.435 to 0.464) × 10-14 quoted to 2 or 3 significant figures ✔

*The size of the triangle can be implied by readings taken from the line.
The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed. Unit not required for the mark.*

**(3)**

(ii) Possible marking points:
The anomalous point makes the value less reliable.✔
(However) the (other) points are close to the line of best fit. Suggesting that the value is reliable. ✔

*If the candidate has not ignored the anomalous point when drawing the line of best fit accept:
The points are not close to the line of best fit so the value is not reliable✔
for one mark only*

**(2)**

(d) (i) Recognition that the gradient = *h*/*e* ✔
*h* = 0.45 × 10-14 × 1.60 × 10-19 ✔
   = (6.95 to 7.44) × 10-34 Js ✔

*Allow ecf from (c)(i) for second mark (including wrong exponent)
Final answer must be in range, have correct exponent, correct unit and be quoted to 2 or 3 sf*

**(3)**

(ii) ((7.2 × 10-34 - 6.63 × 10-34)/ 6.63 × 10-34) × 100%
calculated correctly✔

*Allow ecf from (d)(i): expected answer 8.6%
Allow  giving 7.9%*

 *No sf penalty*

**(1)**

(iii) ± 1.1% or + 1%✔

*± is required here as it is explicit in the question*

**(1)**

(iv) %uncertainty in *f* = 8.6 – 1.1 = 7.5%✔
∴ *δf* = ± 0.075 × 3.19 × 1014 ✔
        = ± 2.39 × 1013 Hz ✔

*Allow ecf from (d)(ii)
Final answer: 2 or 3 sf with unit but ± symbol not required*

**(3)**

**[Total 16]**

**M25.** (a) (i) *W* = 2*mg* cos*φ* ∴*m* = *W*/(2*g* cosφ)✔

*The question says show that, so the candidates must write down both steps.*

**(1)**

(ii) Well drawn straight line of best fit.✔

*The line should follow the trend of the points with an even scatter of points on either side of the line.*

**(1)**

(b) (i) Triangle drawn with smallest side at least 8 cm in length. ✔
Correct readings taken from the line for the triangle ✔
Gradient in the range 0.45 to 0.49 (0.445 to 0.494) quoted to 2 or 3 significant figures ✔

*The size of the triangle can be identified from readings taken from the line.
The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed.*

**(3)**

(ii) Candidate’s answer for gradient in (b)(i) correctly multiplied by *g* (expected answer 4.6)✔
N ✔

*No s.f. penalty.
The second mark is for the unit and can be awarded if the numerical answer is incorrect.*

**(2)**

(c) *δx*% = 0.2 and *δy*% = 0.5✔
*δ(x/y)*% = *δx*% + *δy*% = 0.2 + 0.5 = 0.7 ✔
Use of *δ(x/y*)2% = 2 × *δ(x/y)*(%) ✔

*Final answer is (±) 1.4 (%) which automatically gains all three marks****Otherwise****Accept only 1 s.f. for 1st and/or 2nd marks.
The third mark is for the method, not the final answer*

**(3)**

(d) (i) Systematic errors in measurements are errors which show a pattern or a bias or a trend ✔

*Some acceptable alternatives*

*•* ***A systematic error*** *is one which deviates by a fixed amount from the true value of a measurement*

*• An error which has the same value in all readings*

*• A difference between the true value of a quantity and the indicated value caused by a fault in the measuring device*

*• Accept a good example of systematic error.*

**(1)**

(ii) *y* would be larger✔
because angle *θ* would be smaller
**or**
because friction would be opposing the increasing weight of *m*✔

**(2)**

**[Total 13]**

**M26.**(a) 6.5 × 1010 Pa ✓

**(1)**

(b) kg m-1 s-2 ✓

**(1)**

(c) Direction of movement of particles in transverse wave perpendicular to energy propagation direction✓ **(1)**

Parallel for longitudinal✓ **(1)**

(d) *ρ*1c1=*ρ*2c2✓

*E*=*ρc*2 or *ρc* = seen

**(1)**

 ****

**(1)**

(e) [ and *c*x = 2*c*y ]

0.5✓

**(1)**

(f) speed of the wave in seawater is less than speed of the wave in glass✓

**(1)**

argument to show that water*n* *glass*

**(1)**

so tir could be observed when wave moves from water to glass ✓

**(1)**

**[Total 10]**

**M27.**D

**[Total 1]**

**M28.**(a) Capacitor must not lose charge through the meter ✓

**(1)**

(b) Position on scale can be marked / easier to read quickly etc ✓

**(1)**

(c) Initial current = = 60.0 μA ✓

100 μA or 200 μA ✓ (250 probably gives too low a reading)

Give max 1 mark if 65 μA (from 2.6) used and 100 μA meter chosen

**(2)**

(d) 0.05 V ✓

**(1)**

(e) Total charge = 6.0 x 680 x 10-6 (C) (= 4.08 mC) ✓

Time = 4.08 x 10-3 / 60.0 x 10-6 = 68 s ✓

Hence 6 readings ✓

**(3)**

(f) Recognition that total charge = 65 *t* μC and final pd = 0.098 *t*

so *C* = 65μ / 0.098✓

660 μF ✓ *Allow 663 μF*

**(2)**

(g) (yes) because it could lie within 646 – 714 to be in tolerance ✓

OR

it is 97.5 % of quoted value which is within 5% ✓

**(1)**

(h) Suitable circuit drawn ✓

Charge C then discharge through R and record *V* or *I* at 5 or 10 s intervals ✓

Plot ln *V* or ln *I* versus time ✓

gradient is 1 / *RC* ✓

OR

Suitable circuit drawn ✓

Charge C then discharge through R and record *V* or *I* at 5 or 10 s intervals✓

Use *V* or *I* versus time data to deduce half-time to discharge ✓

1 / *RC* = ln 2 / *t*½ quoted ✓

OR

Suitable circuit drawn ✓

Charge C then discharge through R and record *V* or *I* at 5 or 10 s intervals ✓

Plot *V* or *I* against *t* and find time *T* for *V* or *I* to fall to 0.37 of initial value ✓

*T* = *CR* ✓



*Either A or V required*

*For 2nd mark, credit use of datalogger for recording V or I.*

**(4)**

**[Total 15]**

**M29.**B

**[Total 1]**

**M30.**C

**[Total 1]**

**M32.** (i) C

**(1)**

(ii) B

**(1)**

**[Total 2]**

**M12.** (a) circuit diagram to show:
wide end of conducting strip to – of battery, narrow end to + **(1)**voltmeter between wide end and probe **(1)**

**(2)**

(b) resistance gradient increases as *x* increases **(1)**because strip becomes narrower (as *x* increases) **(1)**current constant throughout strip **(1)**voltage gradient = current × resistance gradient, so
voltage gradient increases as *x* increases **(1)**

**(4)**

(c) (i)

|  |  |
| --- | --- |
| (2*l* – *x*) | ln (2*l – x*) |
| (0.700) | (–0.357) |
| 0.60(0) | –0.511 |
| 0.53(0) | –0.635 |
| 0.47(0) | –0.755 |
| 0.44(0) | –0.821 |
| 0.42(0) | –0.868 |

1st column correct to 2 s.f. **(1)**2nd column correct to 3.s.f. **(1) (1)**

(only 4 values correct, **(1)**)

(ii) suitable scales **(1)**axes labelled and units included **(1)**5 points correctly plotted **(1)**acceptable straight line **(1)**straight line confirms equation because equation is of form
*y* = *mx* + *c* with negative gradient **(1)**

(iii) gradient = (–) = (–) 15.4 (V) **(1)**

1.44 *V*1 = 15.4 gives *V*1 = 11 V **(1)** (10.7 ± 0.2 V)
[alternative: *V* = *V*1 when *x* = *l* and ln (2*l* – *x*) (= ln 0.4) = 0.92 **(1)**at ln (2*l – x*) = 0.92, graph gives *V*1 = 11 V **(1)**  (10.7 ± 0.2 V)]

**(10)**

**[Total 16]**

**M15.**(a) *D* could not be measured with enough **precision**; [can only resolve to 1 sf / 2 dp (and 3 sf / 4 dp needed) / needs to measure to 0.0001 mm] ✓

example given to correctly illustrate this point, eg 0.0855 mm would be read as 0.09 mm ✓

**same** *D* would be produced for different *α* ✓
example given to correctly illustrate this point, eg when *α* = 12° / 14° / 16° ✓

there would be a large **percentage** uncertainty [**percentage** error] in *D* ✓
example given to correctly illustrate this point, eg when *α* = 8° percentage uncertainty is 47% ✓ (tolerate answers using ∆*D* = 0.01 mm or 0.02 mm)

|  |  |  |
| --- | --- | --- |
| *α* / ° | *D* / mmspreadsheet            to 0.01 mm | % uncertainty(∆*D* = 0.01 mm) |
| 2 | 0.0855 | 0.09 | 11.7% |
| 4 | 0.0428 | 0.04 | 23.4% |
| 6 | 0.0285 | 0.03 | 35.1% |
| 8 | 0.0214 | 0.02 | 46.8% |
| 10 | 0.0171 | 0.02 | 58.5% |
| 12 | 0.0143 | 0.01 | 70.2% |
| 14 | 0.0122 | 0.01 | 81.9% |
| 16 | 0.0107 | 0.01 | 93.6% |

**(Max 4)**

(b) argument is not sensible because (larger value of *D* leads to) very small values of *α* ✓
(hence) *α* cannot be measured accurately [uncertainty would be very large] ✓

**(2)**

(c) × 100 ✓ (working must show 0.0859 in denominator, or 0 / 2)

= 0.466% or 0.47% **only** ✓ (ie 0.5% is worth 1 max)

**(2)**

**[Total 8]**