Mark Scheme (RESULTS)

Summer 2018

Pearson Edexcel Level 3 GCE

In Physics (9PH0)

Paper 03 Principles in Physics

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear

  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter

  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. It is not a set of model answers.

1. Mark scheme format

1.1 You will not see ‘wtte’ (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. ‘<u>resonance</u>’

1.2 Bold lower case will be used for emphasis e.g. ‘**and’** when two pieces of information are needed for 1 mark.

1.3 Round brackets ( ) indicate words that are not essential e.g. “(hence) distance is increased”.

1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.

2.2 This does not apply in ‘show that’ questions or in any other question where the units to be used have been given, for example in a spreadsheet.

2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.

2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.

2.5 The mark scheme will indicate if no unit error is to be applied by means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be prevent a mark being awarded if the answer given rounds to the answer in the MS.

3.2 Too few significant figures will mean that the final mark cannot be awarded in ‘show that’ questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.

3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.

3.4 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will mean that one mark will not be awarded. (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 Bald (i.e. no working shown) correct answers score full marks unless in a ‘show that’ question.

4.2 If a ‘show that’ question is worth 2 marks. then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.

4.3 **use** of the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.

4.4 **recall** of the correct formula will be awarded when the formula is seen or implied by substitution.

4.5 The mark scheme will show a correctly worked answer for illustration only.

5. Quality of Written Communication

5.1 Indicated by QoWC in mark scheme. QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.

5.2 Usually it is part of a max mark, the final mark not being awarded unless the QoWC condition has been satisfied.

6. Graphs

6.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.

6.2 Sometimes a separate mark will be given for units or for each axis if the units are complex. This will be indicated on the mark scheme.

6.3 A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.

6.4 Points should be plotted to within 1 mm.

- Check the two points furthest from the best line. If both OK award mark.
- If either is 2 mm out do not award mark.
- If both are 1 mm out do not award mark.
- If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.

  For a line mark there must be a thin continuous line which is the best-fit line for the candidate’s results.

Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)	• Accuracy is (a measure of) how close a measured/calculated value is to the true value **(1)** • Precision is (a measure of) the consistency of values obtained by repeated measurements **(1)**		**2**
1(b)	• Repeat readings can give very similar measurements so value precise **(1)** • Value is not accurate because of a systematic error **(1)**	In MP2 accept zero error or calibration or parallax error for systematic error	**2**

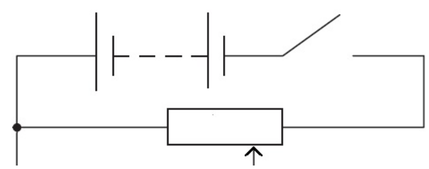
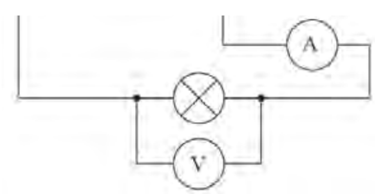
(Total for Question 1 = 4 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
2(a)	• The data has to be collected over a long period of time	(1)		1
2(b)(i)	An explanation that makes reference to the following: • The (terminal) p.d. (of the cell) decreases. • $I = \frac{V}{R}$, so the current decreases as the (external) resistance in the circuit stays constant	(1) (1)	In MP1 do not accept voltage for p.d. MP2: Accept $I \propto V$ because (external) resistance in the circuit is constant, so the current decreases	2
2(b)(ii)	• Use of $I = \frac{V}{R}$ with R = 220 Ω or (220 + r) • (Sum of e.m.f. = sum of p.d. leading to) use of $r = \frac{(\varepsilon - V)}{I}$ with I from MP1 • r = 30 Ω (allow answers in range 28 Ω – 32 Ω)	(1) (1) (1)	Answer in range with no working shown scores MP3 only <u>Example of calculation</u> $I = \frac{3.52\text{ V}}{220\ \Omega} = 1.60\times10^{-2}\text{A}$ $r = \frac{\varepsilon - V}{I} = \frac{(4.0\text{-}3.52)\text{ V}}{1.60\times10^{-2}\text{A}} = 30.0\ \Omega$	3

(Total for Question 2 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
3(a)	Micrometer (screw gauge)	**(1)**	Accept <u>digital</u> calipers	**1**
3(b)	Use of $V = \pi r^2 t$ Use of $\rho = \frac{m}{V}$ to find m Use of 0.5% to find total mass needed Number of discs = 10	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $V = \pi r^2 t = \pi \left(\frac{1.3\times10^{-2}\text{ m}}{2}\right)^2 \times 2\times10^{-3}\text{m}$ $\therefore V = 2.65\times10^{-7}\text{m}^3$ $m = \rho V = 7900\text{ kg m}^{-3}\times2.65\times10^{-7}\text{m}^3$ $\therefore m = 2.10\times10^{-3}\text{kg}$ $\frac{0.1\text{ g}}{M} = 0.5\%$ $\therefore M = \frac{0.1\text{ g}}{0.5/100} = 20\text{ g}$ $\therefore$ number of discs$= \frac{20\text{ g}}{2.10\text{ g}} = 9.5$	**4**
3(c)	% uncertainty calculated for d or t % uncertainty calculated for cross sectional area Uncertainty in volume = (±) 4% [accept 4.0%]	**(1)** **(1)** **(1)**	<u>Example of calculation</u> uncertainty in $d = \frac{0.1\text{ mm}}{13\text{ mm}}\times100\% = 0.77\%$ $\therefore$ uncertainty in $A = 2 \times 0.77\%$ $= 1.5\%$ uncertainty in $t = \frac{0.05\text{ mm}}{2\text{ mm}}\times100\% = 2.5\%$ $\therefore$ uncertainty in V = 1.5% + 2.5% = 4.0 %	**3**

(Total for Question 3 = 8 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
4(a)	• all I values should be recorded to the same number of decimal places **Or** all I values should be recorded to the same resolution	**(1)**	Do not accept same number of significant figures	**1**
4(b)	• Ohm's law requires current to be (directly) proportional to the (applied) p.d • Hence the line should pass through the origin • (There is scatter around the line drawn by the student so) the correct line may be a curve • Conclusion that this graph does not meet the conditions for Ohm's law so the student's statement is invalid	**(1)** **(1)** **(1)** **(1)**	For MP1 accept Ohm's law requires $I \propto V$ In MP2, credit students who check values from graph to see if I doubles when V doubles In MP3, credit students who draw a curve onto the graph MP4 dependent upon MP2 OR MP3	**4**
4(c)	• potential divider circuit diagram drawn as shown • correctly incorporated into the given circuit	**(1)** **(1)**	 Switch not essential, accept potential divider with arrow drawn through resistor  	**2**

(Total for Question 4 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
5(a)(i)	• discards value for l_3 • l_m=85.7 (cm)	**(1)** **(1)**	MP2: answer to 1 d.p. only <u>Example of calculation</u> $l_m = \frac{85.5+86.0+85.5}{3} = 85.7$ cm	**2**
5(a)(ii)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ • T=1.86 s	**(1)** **(1)**	ECF from (i) MP2: accept T = 1.9 s <u>Example of calculation</u> $T = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi \times \sqrt{\frac{0.857 \text{ m}}{9.81 \text{ m s}^{-2}}} = 1.86$ s	**2**
5(b)	**Max 4** from 2 out of 3 pairs • The student should let the pendulum swing back and to before starting the stopwatch. • The first swing may be affected by the student pushing the bob as they release it • The student should use a (fiducial) marker at O • Easier to determine when it passes O • Time more oscillations • A longer time reduces (%) uncertainty (in T)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	For each pair, the second marking point is dependent on the first marking point MP4: Accept the pendulum travelling fastest when it passes O	**4**

(Total for Question 5 = 8 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
6(a)	• See $I = I_1 + I_2$ • Use of $I = \frac{V}{R}$ with the same V for every term • Algebra to show $\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2}$	**(1)** **(1)** **(1)**	If student assumes that $R_1 = R_2 = R \rightarrow R_{\text{eff}} = \frac{R}{2}$, then MP1 and MP2 only For MP3, can assume algebra if equation seen <u>Example of derivation</u> $I = I_1 + I_2 \qquad I = \frac{V}{R}$ $\therefore \frac{V}{R_{\text{eff}}} = \frac{V}{R_1} + \frac{V}{R_2}$	**3**
6(b)	• If two springs are added in parallel the stretching force is shared between the springs • Hence the extension for a given force is half of what it would be for a single spring • So parallel combination has twice the stiffness of a single spring • For two identical resistors in parallel $\frac{1}{R_{\text{eff}}} = \frac{1}{R} + \frac{1}{R}$ • So, adding two equal resistors in parallel halves the effective resistance of the combination • This is in contrast to the springs and so the student's suggestion is invalid (dependent upon MP3 and MP5)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	MP3: Allow parallel combination has a greater stiffness than a single spring MP5: Allow adding two resistors in parallel decreases the effective resistance of the combination Equivalent points for MP4 – MP6 • For two identical resistors in series, $R_{\text{eff}} = R + R$ • So adding two equal resistors in series doubles/increases the effective resistance • This is equivalent to parallel springs, so the student's statement is invalid (dependent upon MP3 and MP5)	**6**

(Total for Question 6 = 9 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
7 (a)	• Use of $\Delta E = L\Delta m$ • Use of $\Delta E = mc\Delta\theta$ • $L = 2.1 \times 10^6$ J kg^{-1}	**(1)** **(1)** **(1)**	In MP1 Δm must be an attempt at a mass difference In MP2 allow any m, $\Delta\theta$ from the question data <u>Example of calculation</u> heat transfer as steam condenses = $(258.3\text{-}255.0)\times10^{-3}\text{kg} \times L$ heat transfer as steam cools = $3.3\times10^{-3}\text{kg}\times4190\text{ J kg}^{-1}\text{ K}^{-1}\times(100\text{-}26)\text{K}$ heat transfer as water is heated = $0.255\text{ kg}\times4190\text{ J kg}^{-1}\text{ K}^{-1}\times(26\text{-}18.5)\text{K}$ $\therefore 3.3\times10^{-3}\text{kg} \times L + 1023\text{ J} = 8013\text{ J}$ $\therefore L = \dfrac{8013\text{ J}-1023\text{ J}}{3.3\times10^{-3}\text{ kg}} = 2.12 \times 10^6\text{ J kg}^{-1}$	**3**
7(b)(i)	An explanation that makes reference to the following: • To bring tubing up to temperature (of steam) • So steam only condenses in the cup **Or** steam doesn't condense in the tubing	**(1)** **(1)**		**2**
7(b)(ii)	• Thermal energy will be transferred from the steam/tubing to the surroundings • Lagging/insulating/shortening the tubing	**(1)** **(1)**	Accept: • Thermal energy is transferred to the cup/ probe • These should have a small a heat capacity	**2**

(Total for Question 7 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
8(a)	• Use of $m = \frac{\text{image height}}{\text{object height}}$ • Use of $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ • $\therefore v = 28$ m	(1) (1) (1)	For MP2 allow ($u \approx f$, so) $v = f \times$ magnification Example of calculation $\frac{v}{u} = \frac{h_i}{h_o} = \frac{0.75\text{ m}}{4.0\times10^{-3}\text{m}} = 187.5$ $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ $\therefore \frac{v}{u} + 1 = \frac{v}{f}$ $\therefore v = (187.5+1)\times15.0\times10^{-2}\text{m} = 28.3\text{ m}$	3
8(b)	**Either** • (Inverse square law states that) the intensity is inversely proportional to the square of the distance **Or** $I \propto \frac{1}{x^2}$ with symbols defined • So $I \rightarrow \frac{I}{4}$ and statement is incorrect **Or** intensity/brightness falls to one quarter and statement is incorrect **OR** • The power is spread over 4 times the area • So intensity/brightness falls to one quarter and statement is incorrect	(1) (1) (1) (1)		2

(Total for Question 8 = 5 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
9(a)	The student's answer should • Include the idea that 'threshold' refers to a (minimum) frequency • state that photons have an energy given by hf • recognise that the energy used to release electrons is called the work function • include the idea that one photon is absorbed by one electron	**(1)** **(1)** **(1)** **(1)**	For MP1, accept that wavelength has to be below a certain 'threshold' **Max 3** if the response is not a discussion of the student's answer	**4**
9(b)	• Photoelectric equation stated in words **Or** $hf = \phi + \frac{1}{2}mv_{\max}^2$ with ϕ defined • Hence $eV_s = hf - \phi$ **Or** $E_{k\max} = hf - \phi$ **and** $E_{k\max} = eV_s$ • Compare with $y = mx + c$ • So plot a graph of V_s against f **Or** plot a graph of eV_s against f • Gradient $= \frac{h}{e}$ **Or** gradient = h	**(1)** **(1)** **(1)** **(1)** **(1)**	MP1: Accept hf_0 for ϕ [with f_0 defined], and $E_{k\max}$ for $\frac{1}{2}mv_{\max}^2$ MP2: eV_s does not have to be the subject of the equation MP5 is dependent upon MP4	**5**

9(c)	• Light consists of (particles called) photons **(1)** • These particles: are discrete packets of energy **Or** are quanta of energy **Or** have momentum **(1)**			**2**

(Total for Question 9 = 11 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
10(a)(i)	• Use of $v = u + at$ • a = 0.81 m s^{-2}	**(1)** **(1)**	Example of calculation $a = \frac{v-u}{t} = \frac{97\text{ m s}^{-1}}{120\text{ s}}$ =0.808 m s^{-2}	**2**
10(a)(ii)	• Use of $s = ut + \frac{1}{2}at^2$ **Or** $v^2 = u^2 + 2as$ **Or** $s = \left(\frac{(v+u)}{2}\right)t$ • Use of $v_{av} = \frac{s}{t}$ with t = 320 s • v_{av} = 75 m s^{-1}	**(1)** **(1)** **(1)**	Ecf acceleration from (a)(i) Example of calculation $s = ut + \frac{1}{2}at^2$=0.5×0.808 m s^{-2} (120 s)^2=5820 m s_2 = 29900 m – 5820 m = 24 080 m t = 440s – 120 s = 320 s $v_{av} = \frac{24\ 080\text{ m}}{320\text{ s}}$ =75.3 m s^{-1}	**3**
10(b)	An explanation that makes reference to the following: • (Magnetic levitation) reduces frictional forces (acting on the train as it moves) • This reduces the work done against friction **Or** this makes it more efficient **Or** there is less time to reach maximum speed **Or** there is a higher maximum speed	 **(1)** **(1)**	 MP1: accept removes/no frictional forces MP2: accept there is less fuel used **Or** less energy is wasted	**2**

*10(c)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.		

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

IC Points	IC Mark	Max linkage mark avail.	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

Indicative content:

1. Removing the magnet from the ring changes the magnetic <u>flux</u> (linked with the ring)
2. This <u>induces an e.m.f.</u> (in the ring)
3. E.m.f. causes a current in the ring
4. Which produces a magnetic field
5. The magnetic fields interact/combine
6. This opposes the change, causing an attractive force to act

IC1: accept references to flux cutting

Alternative indicative content for IC4 – IC5

4. The current is in the magnetic field produced by the magnet
5. The current experiences a magnetic force

6

(Total for Question 10 = 13 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
11(a)	An explanation that makes reference to the following: • The astronauts are in free fall in the space craft **Or** The acceleration of the astronauts and the space station are the same • So there is no contact/reaction force acting on them	**(1)** **(1)**	For MP2, accept a statement that the gravitational force (weight) is the only force acting upon them **Or** all of their weight is used to provide the centripetal force /acceleration	**2**
11(b)	The acceleration (of the platform) is: • (directly) proportional to displacement from equilibrium position • (always) acting towards the equilibrium position **Or** the idea that acceleration is in the opposite direction to displacement [An equation with symbols defined correctly is a valid response for both marks. e.g $a \propto -x$ or $F \propto -x$]	**(1)** **(1)**	Accept towards undisplaced point/fixed point/central point for equilibrium position. Accept a definition in terms of the force i.e. the (resultant) force (on the platform) is: • (directly) proportional to displacement from equilibrium position • (always) acting towards the equilibrium position **Or** the idea that force is in the opposite direction to displacement	**2**
11(c)(i)	• (Use the stopwatch to) time a large number of oscillations to determine the time period • Calculate the frequency using $f = \frac{1}{T}$	**(1)** **(1)**	MP1: At least 5 oscillations required	**2**
11(c)(ii)	• (Use the metre rule to) measure the max displacement of the platform (from the equilibrium position) • Calculate the maximum speed using $v_{\max} = 2\pi f x_{\max}$	**(1)** **(1)**	MP2: allow use of $v_{\max} = \frac{2\pi}{T} x_{\max}$	**2**
11(d)	An explanation that makes reference to the following: • $E_k = \frac{1}{2}mv^2$ **and** $v_{\max} = 2\pi f x_{\max}$ • Max kinetic energy is quadrupled	**(1)** **(1)**		**2**

(Total for Question 11 = 10 marks)

***12(a)**

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

IC Points	IC Mark	Max linkage mark avail.	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

Indicative content:

1. As the temperature of the gas increases the (average) speed/E_k of the atoms increases
2. Greater speed/E_k so the momentum of the atoms increases
3. The rate/frequency of collision of atoms with the container walls increases **Or** the time between collisions with the walls decreases
4. The rate of change of momentum at the walls increases
5. Rate of change of momentum is equal to the force
6. Pressure is $\frac{\text{force}}{\text{area}}$ and the force (on the walls) is greater

IC3 and IC4 must include a mention of the walls/container

6

12(b)(i)	• Conversion of MeV to J **(1)** • See $Q_1 = 79 \times 1.6 \times 10^{-19}$ **and** $Q_2 = 2 \times 1.6 \times 10^{-19}$ **(1)** • Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ **and** $W = QV$ **(1)** • $r = 4.1\times10^{-14}$ m **(1)**		<u>Example of calculation</u> $E_\alpha = 5.5\times10^{6}\text{eV}\times1.6\times10^{-19}\text{J eV}^{-1} = 8.8\times10^{-13}\text{J}$ $8.8\times10^{-13}\text{J} = \frac{79\times1.6\times10^{-19}\text{C}\times2\times1.6\times10^{-19}\text{C}}{4\pi\times8.85\times10^{-12}\text{ F m}^{-1}\, r}$ $r = \frac{3.64\times10^{-26}\text{ N m}^2}{8.8\times10^{-13}\text{ J}} = 4.1\times10^{-14}$ m	**4**
12(b)(ii)	• Electrons are behaving like waves **(1)** • $\text{wavelength} = \frac{h}{\text{momentum}}$ **(1)** • Electron wavelength must be similar to the atomic spacing in the foil **(1)**		MP3: Accept electron wavelength must be similar to the distance between (adjacent) nuclei	**3**
12(c)	• Electrons are excited to higher energy states / levels (by incident electrons) **(1)** • An electron returns to the lower energy state / level resulting in the emission of a <u>photon</u> **(1)** • The energy of the photon is equal to the difference of the energy states / levels **(1)** • Large difference in energy states / levels so as $E = hf$, radiation is high frequency **(1)**		For MP1 and MP2 allow • Electrons knock electrons out of low energy levels • Electrons cascade down to fill up the levels	**4**

(Total for Question 12 = 17 marks)

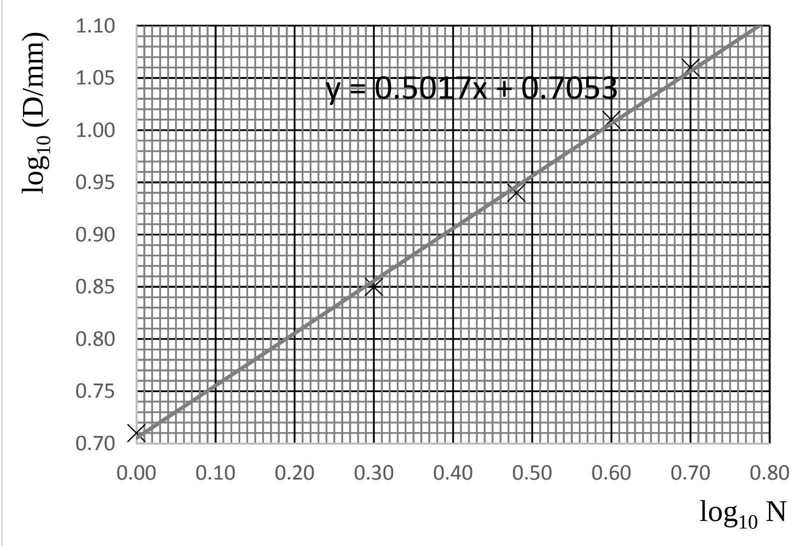
<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>13(a)</td>
<td>

Log values calculated in table
Axes correctly labelled
Suitable scales
All points plotted correctly
Line of best fit drawn
Determine gradient using large triangle
Intercept read from graph
$p = 5.0 – 5.2$ (mm)
Or $p = (5.0 – 5.2) \times 10^{-3}$ (m)
$q = 0.5$

</td>
<td>(1)
(1)
(1)
(1)
(1)
(1)
(1)
(1)</td>
<td>
Accept $\log_{10}$ or ln ($\log_e$)

<table>
<tr><th>$\log_{10}$ (D/mm)</th><th>$\log_{10}$ N</th></tr>
<tr><td>0.710</td><td>0.000</td></tr>
<tr><td>0.850</td><td>0.301</td></tr>
<tr><td>0.940</td><td>0.477</td></tr>
<tr><td>1.01</td><td>0.602</td></tr>
<tr><td>1.06</td><td>0.699</td></tr>
</table>

<table>
<tr><th>ln (D/mm)</th><th>ln N</th></tr>
<tr><td>1.64</td><td>0.000</td></tr>
<tr><td>1.96</td><td>0.693</td></tr>
<tr><td>2.16</td><td>1.10</td></tr>
<tr><td>2.33</td><td>1.39</td></tr>
<tr><td>2.44</td><td>1.61</td></tr>
</table>



</td>
<td>8</td>
</tr>
</table>

13(b)(i)	• absolute uncertainty in position × 2 **(1)** • % uncertainty = 0.2 % **(1)**		<u>Example of calculation</u> Absolute uncertainty = 2 × 0.005 mm = 0.01 mm $\therefore$% uncertainty= $\frac{0.01 \text{ mm}}{5.13 \text{ mm}} \times 100\% = 0.2$ %	**2**
13(b)(ii)	• The edges of the dark circle are not clearly defined	**(1)**	Accept: the rings are not perfect circles	**1**
13(c)	• Coherent waves have a constant phase relationship **(1)** • Coherent waves have the same frequency **(1)** • However, for each frequency present the (two) reflected waves are coherent **(1)** • Hence with a non-monochromatic source, a set of dark rings for each frequency would be produced **(1)**		MP2-4: accept wavelength for frequency MP4: hence with a white light source you would see a set of coloured rings	**4**

(Total for Question 13 = 15 marks)

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