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Mark Scheme June 2009

GCE

GCE 08 Physics (8PH01)

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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.

For example:

(iii) Horizontal force of hinge on table top

66.3 (N) or 66 (N) **and** correct indication of direction [no ue] ✓ **1**
[Some examples of direction: acting from right (to left) / to the left / West / opposite direction to horizontal. May show direction by arrow. Do not accept a minus sign in front of number as direction.]

This has a clear statement of the principle for awarding the mark, supported by some examples illustrating acceptable boundaries.

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. 'resonance'
1.2 Bold lower case will be used for emphasis.
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 cause the final calculation mark to be lost.
2.2 Incorrect use of case e.g. 'Watt' or 'w' will **not** be penalised.
2.3 There will be no unit penalty applied in 'show that' questions or in any other question where the units to be used have been given.
2.4 The same missing or incorrect unit will not be penalised more than once within one question.
2.5 Occasionally, it may be decided not to penalise a missing or incorrect 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.
2.6 The mark scheme will indicate if no unit error penalty is to be applied by means of [no ue].

3. Significant figures

3.1 Use of an inappropriate number of significant figures in the theory papers will normally only be penalised in 'show that' questions where use of too few significant figures has resulted in the candidate not demonstrating the validity of the given answer.

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.

4.6 Example of mark scheme for a calculation:

'Show that' calculation of weight

Use of L × W × H ✓

Substitution into density equation with a volume and density ✓

Correct answer [49.4 (N)] to at least 3 sig fig. [No ue] ✓
[If 5040 g rounded to 5000 g or 5 kg, do not give 3rd mark; if conversion to kg is omitted and then answer fudged, do not give 3rd mark]
[Bald answer scores 0, reverse calculation 2/3] **3**

Example of answer:

80 cm × 50 cm × 1.8 cm = 7200 cm^3

7200 cm^3 × 0.70 g cm^{-3} = 5040 g

5040 × 10^{-3} kg × 9.81 N/kg

= 49.4 N

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.

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.

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

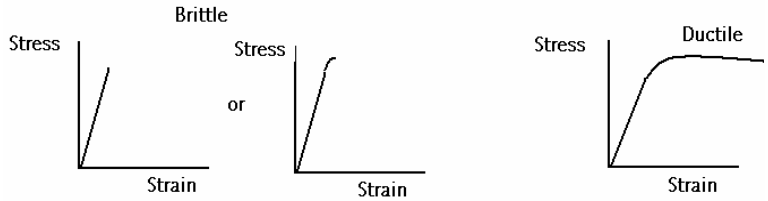
Unit 1 6PH01_01

Question Number	Answer	Mark
1	B	**(1)**
	Total for question	**1**

Question Number	Answer	Mark
2	A	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
3	C	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
4	D	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
5	A	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
6	B	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
7	B	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
8	C	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
9	D	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
10	A	**(1)**
	Total for question	**1**

Question Number	Answer	Mark
11(a)	Explain the difference between scalar quantities and vector quantities. It must mention direction or give an e.g. with direction. [Vectors have direction 1 mark. Scalars don't have direction 1 mark] scalar – magnitude/size only but vector – magnitude/size and direction (1) (accept vector has direction but scalar doesn't)	1
11(b)	Comment on this statement. (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) velocity is: a vector / speed in a given direction / = displacement/time / = (total distance in a particular direction)/time [accept references to velocity being postive and negative / changing direction] (1) end and start at the same place / distance in any direction is zero / displacement = 0 (1) so it's true – (ave) vel = zero (1) (consequential on 2nd mark)	3
	Total for question	**4**

Question Number	Answer	Mark
12 (a)	Add to the diagram to show the water flow at A_2 and B_2. Laminar at A_2 – minimum 2 lines, approximately straight and parallel, lines mustn't cross (1) Turbulent at B_2 – indicated by lines crossing / change in direction > 90°/ chaotic lines(1)	**2**
12 (b)	Name and describe the type of water flow at A_2 and at B_2. A - laminar flow / streamline flow (1) no abrupt change in (direction or speed of) flow/ flows in straight lines / velocity at any point constant / no mixing of layers [no eddies is not sufficient; smooth is not sufficient; no disruption of lines not sufficient](1) B - turbulent flow (1) mixing of layers / eddies / sudden change in (direction or speed of) flow / velocity at a point not constant (1) [NB - All independent marks]	**4**
	Total for question	**6**

Question Number	Answer	Mark
13(a)	Explain the meanings of the terms brittle and ductile. brittle – undergoes no / little plastic deformation (before breaking) / tends to break when subject to impact [accept breaks just beyond / soon after limit of proportionality / elastic limit] (1) graph (1) ductile – undergoes a lot of plastic deformation (before breaking) / able to undergo permanent deformation under tensile stress / can be drawn into wires (1) graph (1) [Assume axes labels if not given, accept force, extension labels] [1 graph mark max if stress strain labels reversed] [Ductile graph can be curved from start] 	**4**
13(b)	give an example of a ductile material and situation where behaviour desirable material example, e.g. copper (accept metal or any metal) (accept chewing gum, silly putty …) (not rubber)(1) example of desirable application, e.g. making wires (1) [NB Not examples of moulding or malleable behaviour]	**2**
	Total for question	**6**

Question Number	Answer	Mark
14(a)	Use the displacement-time graph to find the speed of the object at time t = 4 s. Draw a tangent (accuracy marked in final part) or state use gradient (1) Use of speed = distance/time for values from graph (i.e. on gradient or curve) (1) Correct answer [8.0 ± 0.5 m s^{-1}] (1) [no ecf for values taken] Possible alternative – state or use $s = (u + v)t/2$ (1), correct substitution (1), correct answer (1) (speed from curve values then x 2 gains these 3 marks) *Example of calculation* v = (32 m – 0 m) / (6.0 s – 2.0 s) = 8.0 m s^{-1}	**3**
14(b)	Calculate the acceleration. Use of $v = u + at$ with previous answer OR use of $s = ut + 1/2\ at^2$ with values from graph (1) Correct answer [2 m s^{-2}] (1) [allow ecf] *Example of calculation* $a = (v – u) / t$ = (8.0 m s^{-1} – 0) / 4 s = 2 m s^{-2}	**2**
	Total for question	**5**

Question Number	Answer	Mark
15 (a)	Free body diagram. Weight / W / mg (NOT 'gravity') – correctly labelled arrow (allow force/pull of gravity) (1) Normal contact force / force/push of table / 'reaction' / R – correctly labelled arrow (1) [3 forces labelled – max 1mark, 4 forces – no marks BUT ignore upthrust.] [The free-body diagram does not have to include the bottle but the forces must be co-linear for the second mark]	**2**
15 (b)	Give a corrected explanation. ***(Newton) 3rd law*** → *eq and opp (1)* by **(Newton) 1st law** (accept 2nd law) (1) forces balanced → no **acceleration** / no **change in velocity** / **remains at rest** (1) [Bold type indicates required changes]	**3**
	Total for question	**5**

Question Number	Answer	Mark
16(a) (i)	Show that the power available to the turbine is about 40 kW. Use of density = *m/V* (1) Use of gpe = *mgh* (1) Correct answer [38 000 W] (1) [no ue] *Example of calculation* volume in 1 s = 0.13 m^3 mass = density x *V* = 1000 kg m^{-3} x 0.13 m^3 (1) = 130 kg gpe lost = *mgh* = 130 kg x 9.81 N kg^{-1} x 30 m = 38 000 J in one second, so power = 38 000 W [1000 kg m^{-3} x 0.13 m^3 x 9.81 N kg^{-1} x 30 m = 38 000 W gets 3 marks]	**3**
16(a) (ii)	Suggest a reason for output only 6 kW friction e.g. in turbine, in fluid / flow rate lower / heat due to friction [accept (electrical) resistance in turbine] (1)	**1**
16(b) (i)	Calculate maximum output of solar system for 6 hours Use of energy = power x time(1) Correct answer [216 MJ] (1) *Example of calculation* Energy = power x time = 10 000 W x 6 x 60 x 60 s = 2.16 x 10^8 J [216 000 000 J, 216 MJ, 216 000 kJ]	**2**
16(b) (ii)	Discuss suitability of output of diesel generators Renewables – 100 + 6 + 6 + 24 + 10 = 146 kW [accept 140 kW], vs diesel 160 kW (1) Backup must be enough to replace whole of renewable amount / diesel power greater than or approximately equal to renewable(1)	**2**
	Total for question	**8**

Question Number	Answer	Mark
17(a) (i)	Label the diagram Upthrust / *U* – upward arrow [accept buoyancy force] (1) Viscous drag / drag / friction / *F* / *V* / *D* – downward arrow [accept water resistance](1) [Arrows do not have to be on the bubble]	**2**
17(a) (ii)	Explain why a steady upwards speed is reached. Initially viscous drag = 0 / is very small / resultant force is upwards / $U > W$ / $U > W + F$ (1) Viscous drag increases (1) (Until) forces balanced (1) Therefore: no acceleration / uniform velocity / terminal velocity / const speed (1) Must be a clear link to balanced forces to allow mark 4, even if mark 3 not awarded	**4**
17(a) (iii)	Write an expression for the forces (-) Upthrust = Viscous drag + Weight; Upthrust + Viscous drag + Weight = 0 (1) [Allow ecf from diagram] [Accept symbols]	**1**
17(b) (i)	Justify decision to ignore weight of air Density of air much less than density of (any) liquid (1) So weight << upthrust / weight << viscous drag / weight << other forces(1) (not consequential) ('W negligible' alone not sufficient)	**2**
17(b) (ii)	Explain what would happen if temperature increased viscosity decreases (1) speed/velocity would be greater (1)	**2**
17(b) (iii)	Use expression to explain larger bubble catching smaller bubble If r increases so speed increases (1)	**1**
	Total for question	**12**

Question Number	Answer	Mark
18(a)	Show that the work done on the cork is about 4 J. Use of work = force x distance (1) Correct answer [3.75 (J)] (1) [no ue] Example of calculation work = force x distance = 150 N x 2.5 x 10^{-2} m = 3.75 J	**2**
18(b)	Calculate the speed of cork Use of ke = 1/2 mv^2 (1) Correct answer [32 m s^{-1}] (1) [allow ecf] Or Use of $a = F/m$ **and** $v^2 = u^2 + 2as$ (1) Correct answer (1) Example of calculation 3.75 J = 1/2 x 0.0075 kg x v^2 v^2 = 1000 m^2 s^{-2} v = 31.6 m s^{-1} [4 J then ke = 32.7 m s^{-1}]	**2**
18(c) (i)	Show that the vertical component of the velocity is about 20 m s^{-1}. Correct answer [21 (m s^{-1})] [no ue] *Example of calculation* $v_v = v \sin \theta$ = 32 m s^{-1} x sin 40° = 20.6 m s^{-1}	**1**
18(c) (ii)	Calculate distance travelled by cork Horizontal component (1) Use of appropriate equation of motion, e.g. $v = u + at$ (1) Time of flight (1) Use of velocity = distance / time (1) Correct answer [103 m] (1) [allow ecf for vertical component] [missing factor of 2 for time of flight → max 3 marks] *Example of calculation* $v_h = v \cos \theta$ = 32 m s^{-1} x cos 40° = 24.5 m s^{-1} Time to max height, $t = (v - u)/a$ = 20.6 m s^{-1} / 9.81 m s^{-2} = 2.1 s Total time = 2 x 2.1 s = 4.2 s range = v x t = 24.5 m s^{-1} x 4.2 s = 103 m	**5**
18(d)	Explain difference to world record	

	If previous answer is larger than 53 m: Air resistance/friction on cork as it leaves the bottle (1) Work done → energy dissipated OR air resistance decelerates cork / reduces speed of cork OR friction with bottle reduces acceleration/launch speed OR reduces ke of cork(1) Accept different angle (1) greater than 50°/ less than 40° reduces range (1) Accept different pressure (1) Lower pressure reduces initial force (1) Accept wind blowing against cork (1) Decelerate cork (1) Accept different cork mass (1) larger mass gives smaller initial speed (1) BUT if start off saying 45° / higher pressure / smaller mass – no marks out of 2 because these would increase range ETC. If previous answer is smaller than 53 m: Accept different angle (1) between 50° and 40° (or 45°) increases range (1) Accept different pressure (1) higher pressure increases initial force (1) Accept wind blowing behind cork (1) Accelerates cork (1) Accept different cork mass (1) smaller mass gives higher initial speed (1)	**2**
	Total for question	**12**

Question Number	Answer	Mark
19(a)	Force diagram Accept free body or triangle/parallelogram of forces Downward arrow labelled Weight/*W*/*mg* (1) Arrows parallel to both lines, at least one labelled tension/*T*(1) Minus 1 for each additional force	**2**
19(b) (i)	Show that downward vertical force is about 11 N Correct answer (10.8 N) (1) [no ue] *Example of calculation* $W = mg$ $= 1.1 \text{ kg} \times 9.81 \text{ N kg}^{-1}$ $= 10.8 \text{ N}$	**1**
19(b)(ii)	Show that the angle is about 84°. Correct use of sides in right angled triangle (1) Correct answer [84.2°] (1) [no ue] *Example of calculation* $\tan \theta = 4.80 \text{ m} / 0.485 \text{ m}$ Angle = 84.2° (Accept use of cos instead of tan)	**2**

19(b) (iii)	Show that the tension on the line is less than 60 N Use of trigonometrical function for vertical component of tension (1) Correct answer [53 N] (1) [allow ecf] [no ue] Example of calculation $T_v = T \cos \theta$ $W = 2\ T \cos \theta$ T = 10.8 N / 2 x cos 84.2 = 53.4 N Alternative answers range from 51 N to 55 N	**2**
19(b) (iv)	Calculate the strain Calculate extension (1) correct answer [2.6×10^{-2}] (1) *Example of calculation* extension = 9.847 m – 9.6 m = 0.247 m strain = 0.247 m / 9.6 m = 2.6×10^{-2} [2.6%]	**2**
19(c)	Calculate Young's modulus Use of stress = force / area (1) Use of E = stress / strain (1) Correct answer [3.1×10^8 Pa] [3.1×10^8 N m^{-2}] (1) [allow ecf, including use of F = 60 N] [Substituting into $E = (F/A)/(e/l)$ in one go gets both use of marks] $E = (F/A)/(e/l)$ = (53.4 N / 6.6×10^{-6} m^2) / 2.6×10^{-2} = 3.1×10^8 Pa (accept answers in range 3.0×10^8 Pa to 3.6×10^8 Pa for alternative F values)	**3**
	Total for question	**12**

Unit 2 6PH02_01

Question Number	Answer	Mark
1	C	**(1)**
	Total for question	**1**

Question Number	Answer	Mark
2	D	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
3	B	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
4	B	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
5	C	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
6	A	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
7	B	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
8	D	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
9	A	**(1)**
	Total for question	**1**
Question Number	Answer	Mark
10	A	**(1)**
	Total for question	**1**

Question Number	Answer	Mark
11	Use of $V = IR$ to find total resistance **or** terminal p.d.	**1**
	Subtraction of resistance **or** p.d.s	**1**
	r = 8.2 Ω (accept 8 Ω)	**1**
	OR see $E = I(R+r)$	**1**
	Substitution of values into equation	**1**
	r = 8.2 Ω (accept 8 Ω)	**1**
	Example of answer	
	Total R = 1.5 V ÷ (17 × 10^{-3} A) = 88.2 Ω	
	r = 88.2 – 80 = 8.2 Ω	
	Total for question	**3**

Question Number	Answer	Mark
12	Attempt to use $I = Q / t$	**1**
	use of e = 1.6 × 10^{-19}	**1**
	I = 2.8 × 10^{6} A [C s^{-1}]	**1**
	[omit e gives answer 1.73 × 10^{25} scores 1]	
	Example of answer	
	I = (2.6 × 10^{26} × 1.6 × 10^{-19} C) ÷ 15 s	
	I = 2.77 × 10^{6} A	
	Total for question	**3**

Question Number	Answer	Mark
13(a)	Diffraction is the spreading out of the wave	1
	As it passes through an aperture/around an obstacle	1
(b) (i)	Electrons can behave as waves **OR** electrons have wave like properties **OR** electrons act like wave particles	1
(ii)	λ ≈ spacing/gap between atoms **OR** the size of the atoms **OR** spacing/gap in the graphite	1

	Total for question	4

Question number	Answer	Mark
14(a)	Doppler	1
(b)	**MAX 3** **Ambulance moving towards**, higher frequency/pitch (1) Wavelength shorter/waves bunch together (1) **Ambulance moving away**, lower frequency/pitch (1) wavelength increased/waves spread out (1) (wavelength marks may be awarded on a diagram)	
		Max 3
(c)	Reference to a higher/lower frequency/wavelength/pitch scores 1 Change in frequency is greater **OR** even higher/ lower frequency **OR** range of frequencies greater scores 2	
		2
	Total for question	**6**

Question Number	Answer	Mark
15(a)	Use of $V=IR$ V = 3.0 V	**1** **1**
(b)	pd across 30 Ω resistor = 6.0 V ecf their answer (a) I_2 = 6.0/30 = 0.20 A	**1** **1**
(c)	I_1 = 0.60 – 0.20 = 0.40 A R = 15 Ω full ecf their answer for I_2 and their V across 30 Ω	**1** **1**
	Total for question	**6**

Question Number	Answer	Mark
16	The answer must be clear and organised in a logical sequence • Different currents / current divides in parallel circuit(1) • • Same potential difference/voltage across each lamp (1) • • Use of $P = V^2 / R$ **OR** $P = VI$ if identified $I_A < I_B$ (1) • Leading to high resistance, smaller power (1) • • lamp B will be brighter/ lamp A dimmer (1) • • Each electron loses the same energy (1) • There are more electrons/sec in B (1) • Hence greater total energy loss /sec in B (1)	
		Max 5
	Total for question	**5**

Question Number	Answer	Mark
17 (a)	A statement which implies only certain energies are allowed e.g. Allowed/possible energy of atom/electron (in an atom) Discrete energy of an atom/electron One of the energies of the atom/electron Energy an atom/electron can have	**1**
(b)	Photon is a (discrete) package/packet/quantum of (electromagnetic) energy/particle of light	**1**

(c)	(energy of) E_2 – (energy of)E_1	**1**
(d)	See $E = h\,c\,/\,\lambda$ **OR** use of $v = f\lambda$ Substitution into $E = h\,c\,/\,\lambda$ **OR** use of $E = hf$ $E = 3.14 \times 10^{-19}$ J or 1.96 eV **Example of answer** $E = (6.63 \times 10^{-34}$ Js $\times 3 \times 10^{8}) \div 6.33 \times 10^{-7}$ m $E = 3.14 \times 10^{-19}$ J	**1** **1** **1**
	Total for question	**6**

Question Number	Answer	Mark
18	Addition of words (order essential) photon metal energy (allow mass, charge, momentum) (photo)electron work function (of the metal)	 **1** **1** **1** **1** **1**
	Total for question	**5**

Question Number	Answer	Mark
19(a)	Ray drawn along edge of prism (labelled X) **(**ignore a reflected ray)	**1**
(b)(i)	$n = 3 \times 10^{8} \div 1.96 \times 10^{8}$ n = 1.53 (no unit, ue if one given)	**1** **1**
(b)(ii)	Use of sin (critical angle) = 1/ n **OR** use of sin i/sin r = v_1/v_2 = n c = 41°	**1** **1**
(c)	Red light: refraction towards normal at first face but less than refraction for blue light Refracts into air at second face with angle in air > angle in glass	**1** **1**
	Total for question	**7**

Question Number	Answer	Mark
20(a)	The answer must be clear, organised in a logical sequence and uses specialist vocabulary	
	Interference (pattern) produced / superposition occurs/ standing wave formed	**1**
	Maxima related to constructive interference/antinode **and/or** minima related to destructive interference/node	**1**
	Maxima/antinode formed where the waves are in phase / path difference nλ	**1**
	Minima/node formed where the waves are in antiphase / path difference = (n+½)λ	**1**
	[out of phase is not sufficient]	
(b)(i)	Distance between adjacent maxima = λ/2	**1**
	Wavelength = 0.1 m	**1**
(b)(ii)	Use of $v = f\lambda$ with their λ from (b)(i)	**1**
	Speed = 330 m s^{-1} ecf their λ	**1**
	Example of answer	
	v = 3300 × 0.1	
	v = 330 m s^{-1}	
(c)(i) and (ii)	(mark (i) and (ii) as one section	
	(minima never zero) because there is not complete cancellation/overall displacement is not zero/ not total destructive interference	**1**
	Because the waves have different amplitudes/amplitude decreases with distance	
	OR	
	energy loss due to reflection or spreading out	

	OR reflection off other surfaces As the microphone moves towards the plate, the path difference decreases Amplitudes (of waves) get similar	**1** **1** **1**
	Total for question	**12**

Question Number	Answer	Mark
21(a)	<u>Effect of stretching wire</u> Refers to $R = \rho l / A$ Increasing length leads to increase in resistance Decreasing area leads to increase in resistance [must relate thinner to area] [last two points may be combined to give single statement, can score both marks]	 **1** **1** **1**
(b)	<u>Resistance calculation</u> Use of $R = \rho l / A$ × 8 R = 0.22 (Ω) [Omitting x8 gives R = 0.028 Ω scores 1] **Example of answer** $R = (9.9 \times 10^{-8}\ \Omega\ m) \times (8 \times 0.025\ m) \div 0.9 \times 10^{-7}\ m^2$ R = 0.22 Ω	 **1** **1** **1**
(c) **(i)**	<u>Relationship and increase in R</u> Attempts to substitute for $A = V/l$ in $R = \rho l / A$ $R = \rho l^2 / V$	 **1** **1**
(ii)	Any attempt to relate original resistance of gauge to 2.5^2 (possibly × 8, cm or m) Relates this to resistance associated with increase in length Change in resistance = $1.76 \times 10^{-3}\ \Omega$ **OR** Uses $V = lA$ to find new area Uses this A with new length to find new R Change in resistance = $1.76 \times 10^{-3}\ \Omega$ [if candidate assumes A constant and finds new R and ΔR = 0.001 Ω, score 1 mark] **Example of answer**	**1** **1** **1** **1** **1** **1**

	New $R = \left(\frac{2.51^2}{2.5^2} \times 0.22\right) - 0.22$ $\Delta R = 1.76 \times 10^{-3}\ \Omega$	
(d)	<u>Zigzag pattern</u> Each section of wire increases in length/gives a longer total length/long wire in small space Small change in length of gauge leads to larger change in resistance	**1** **1**
	Total for question	**13**

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