Mark scheme – Physical Quantities

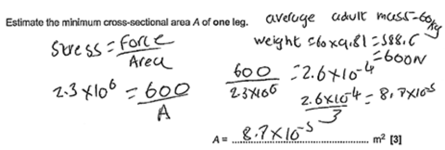
Question			Answer/Indicative content	Marks	Guidance
1			Line of best fit drawn through the data points Gradient = 38 (Ckln2 = gradient) $1.2 \times 10^{-3} \times k \times \ln 2 = 38$ $k = 4.6 \times 10^4$ (Ω m^{-1})	B1 C1 C1 A1	Allow ± 2. Not calculated through use of a single point. Possible ECF from incorrect gradient **Note**: gradient of 40 gives 4.8×10^4 and gradient of 36 gives 4.3×10^4 **Examiner's Comments** This question is likely to be an unfamiliar scenario to many candidates and so required some careful reading. The first mark is for a single straight line of best fit; many candidates simply joined up the first and last point, which produced a line that did not produce an even distribution of points above and below. The gradient calculation was well done by most candidates, leading to a value within the tolerance. Although the given equation is likely to be unknown, most candidates were able to appreciate how to determine the value of k and did so successfully. Over half of the candidates were able to achieve full marks on this question.
			Total	**4**	
2	a	i	$l = (v/4)(1/f) - k$ Correct comparison with $y = mx + c$	M1 A1	Correct manipulation of equation **must** be shown
		ii	large triangle used to determine gradient gradient calculated correctly v =320 (m s^{-1})	B1 B1 B1	$\Delta x > 0.6 \times 10^{-3}$s Expect between 80 and 82 (m s^{-1}) **Allow** 320 ± 20; **allow ECF** from an incorrect gradient
	b	i	Value of $1/F$ determined correctly from graph F = 350 (Hz)	C1 A1	**Allow values between** 2.83×10^{-3}s and 2.84×10^{-3}s **Allow** only alternative methods which use values from line of best fit
		ii	(100 ($\Delta F/F$) =) 100 $\Delta v/v$ $+ \dfrac{100\,(\Delta l + \Delta k)}{(l + k)}$	B1 B1	

			Total	**9**	
3	a		At t = 0 (and t = 15, 30) the (magnitude of the) centripetal force equals $R - W$ (as only vertical forces act on the tourist)	B1	**Allow** at t = 0 (**or** the bottom of the circle) the centripetal force is provided by the resultant/ upwards/vertical force
	b	i	(For circular motion) there must (always) be a resultant force towards the centre The resultant force is not always vertical/sometimes has a horizontal component This can only be provided by friction/cannot be provided by R and W / R and W are always vertical/only F is horizontal	B1 x 2	any 2 from 3 marking points **Allow** F provides the horizontal (component of the) centripetal force
		ii	Sine wave with period 30 min and amplitude 0.050 (N) Correct phase, i.e. <u>negative</u> sine wave	B1 B1	Must start at the origin
		iii	F = 0.050 cos 40° F = 0.038 (N)	C1 A1	**Allow** alternative methods e.g. triangle of forces **Allow ECF** from graph if used
	c		$m = 650/g$ **or** m = 650/9.81 (= 66.3 kg) ($F = mr\omega^2$ gives) $d = 0.050 / m\omega^2$ = 0.050 / 66.3 x $(3.5 \times 10^{-3})^2$ d = 62 (m)	C1 C1 A1	**Not** m = 650 kg or m = 65 kg **or** ($F = mv^2/r$ and $v = 2\Pi r/T$ gives) $d = 0.050 \times (30 \times 60)^2 / (4\pi^2 \times 66.3)$
			Total	**10**	
4	a	i	GPE = (−) GMm/r GPE = (−) $6.67 \times 10^{-11} \times 2 \times 10^{30} \times 810/1.5 \times 10^{11}$ GPE = (−) 7.2×10^{11} (J)	C1 C1 A0	Mark is for full substitution, including 6.67×10^{-11} for G
		ii	$v = 2\Pi r/T = 2\Pi \times 1.5 \times 10^{11} / 3.16 \times 10^7$ (= 29.8 km s^{-1}) KE = $\frac{1}{2}mv^2 = 0.5 \times 810 \times (29.8 \times 10^3)^2$ KE = 3.6×10^{11} (J)	C1 M1 A1	**Allow** proof by algebraic method for full marks e.g. $mv^2/r = GMm/r^2$ so $mv^2 = GMm/r$ Therefore KE/GPE = $\frac{1}{2}mv^2/(GMm/r) = \frac{1}{2}$
		iii	total energy = (−) $(7.2 \times 10^{11} - 3.6 \times 10^{11})$ total energy = (−) 3.6×10^{11} (J)	M1 A0	working must be shown; **ECF (i) and (ii)**
	b	i	<u>***A =***</u> $470/8.8 \times 10^{-13} = 5.3 \times 10^{14}$ (Bq) $\lambda = \ln 2/(88 \times 3.16 \times 10^7)$ (= 2.5×10^{-10} s^{-1}) ($A = \lambda N$); N (= $5.3 \times 10^{14} / 2.5 \times 10^{-10}$) = 2.1×10^{24}	C1 C1 A1	Mark is for correct calculation of A (in Bq **or** decays per s) Mark is for correct working to give λ in s^{-1}
		ii	$P = P_o \exp(-\lambda t)$	C1	**Allow** formula in terms of N or A

			P = 470 exp (− ln 2 x 100 / 88) P = 210 (W)	C1 A1	**Allow** calculation in terms of N or A; **allow ECF** for N or A
			Total	**12**	
5			**Level 3 (5 - 6 marks)** Clear explanation using kinetic theory ideas **and either** a clear proof using formulae **or** a correct calculation *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3 – 4 marks)** A partial explanation using kinetic theory ideas **and either** a partial proof using formulae **or** a partial calculation *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** An attempt at either explanation **or** proof **or** calculation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	B1 x 6	**Indicative scientific points may include:** **Explanation using kinetic theory** • pressure = force/area • force is caused by air molecules colliding with oven walls • Newton's 2nd Law states force = rate of momentum change • increased temperature means each molecule has greater KE • hence greater velocity and hence greater momentum • and more collisions with walls per second • hence greater rate of momentum change on hitting walls. • This would lead to greater pressure if N remained constant • so number of molecules in oven must decrease (air escapes) • so fewer but 'harder' collisions at higher temperatures giving constant pressure. • Rms velocity c increases with temperature but number N decreases and so effects balance out to keep total KE ($\frac{1}{2}Nmc^2$) constant **Proof using formulae** • equate $pV = NkT$ and $E = \frac{3}{2}NkT$ to show $E = \frac{3}{2}pV$ • in an ideal gas, all internal energy E is kinetic energy • so E is independent of temperature **Calculation** • Internal energy $= \frac{3}{2}pV$ = 1.5 x 0.065 x 1.0 x 10^5 = 9.8 kJ • At T = 293K, $N = pV/kT$ = 1.6 x 10^{24} and n = 2.7 moles • At T = 473K, N = 1.0 x 10^{24} and n = 1.7 moles

					• so we can show that NT (and/or nT) remain constant
			Total	**6**	
6	a	i	($F = ma$ =) 190 × 10^3 = 2.1 × 10^5 a a = 0.90 (m s^{-2})	M1 A0	a = 0.905 to 3 SF
		ii	($v^2 = u^2 + 2as$ gives) 36 = 2 × 0.90 × s s = 20 (m)	C1 A1	**Allow** any valid suvat approach; **allow ECF** from (i) **Note** using a = 1 gives s = 18(m)
		iii	**1** $P = Fv$ One correct calculation e.g. F = 100 × 10^3 and v = 42 gives P = 4.2 ×10^6 (W) Fv = constant **2** (P = VI = 4.2MW so) 4.2 × 10^6 = 25 × 10^3 × I I = 170 (A)	B1 B1 B1 C1 A1	Equation must be seen (not inferred from working) **Allow** any corresponding values of F and v; working must be shown. No credit for finding area below curve **Allow** F is proportional to 1/v or graph is hyperbolic *or* correct calculation of Fv at two points (or more) **Allow** P = 4MW or **ECF from (iii)1** Expect answers between 160 - 170 (A)
	b	i	R (= ρL/A) = 1.8 × 10^{-8} × 1500/1.1 × 10^{-4} R = 0.25 (Ω)	C1 A1	
		ii	$E = \sigma/\varepsilon = T/A\varepsilon$ (so $T = EA\mathcal{E}$) T = 1.2 x 10^{10} x 1.1 x 10^{-4} x 0.013 T = 1.7 x 104 (N) or 17 (kN)	C1 C1 A1	**or** calculation of σ =1.56 x 10^8 (Nm^{-2}) **or** T = 1.56 x 10^8 x 1.1 x 10^{-4}
			Total	**13**	
7		i	R = 3000 + 1500 V = 12 × 1500/4500 = 4(.0) (V)	C1 A1	R = 4500 (Ω) **or** $I = V/R$ = 12 /4500 = 2.67 mA V_{1500} = 2.67 mA x 1.5 kΩ = 4.0 (V)
		ii	V (= 12 × 1500/1600) = 11.25 (V) ΔV = 11.25 – 4.0 = 7.25 (V)	C1 A0	
			Total	**3**	
8		i	$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{490 \times 10^{-9}}$ energy = 4.1 × 10^{-19} (J)	C1 A1	**Note** answer to 3 SF is 4.06 × 10^{-19}

		ii	(number of photons =) $\frac{0.230}{4.06 \times 10^{-19}}$ number of photons = 5.7×10^{17}	C1 A1	Possible ECF from **(b)(i)** **Note** answer is 5.6×10^{17} when 4.1×10^{-19} is used
			Total	**4**	
9			**D**	1	
			Total	**1**	
10			$h \rightarrow$ J s / $h \rightarrow$ N m s / J $\rightarrow$ kg m^2 s^{-2} base unit = kg m^2 s^{-1}	C1 A1	
			Total	**2**	
11		i	sensible diameter, e.g. 7 (mm) (power = $4.8 \times 10^{-7} \times \pi \times (0.0035)^2$) power = 1.8×10^{-11} (W)	C1 A1	**Allow** 2 − 16 (mm) **Not** πd^2; this is XP **Note check for AE** (condone rounding error here) Possible ECF for diameter outside the range 2 − 16 (mm) **Allow** 1 SF answer here
		ii	($I \propto A^2$; intensity doubles) $A = \sqrt{2} \times 7.8$ (or equivalent) A = 11 (nm)	C1 A1	**Allow** the C1 mark for 4.8 (× 10^{-7}) = k × [7.8 × (10^{-9})]^2
			Total	**4**	
12			C	1	
			Total	**1**	
13			(Mass of adult =) 50 kg to 150 kg or W = 500N to 1500 N $\text{Area} = \frac{\text{weight}}{2.3 \times 10^{n}}$ $\text{Area} = \frac{1}{3} \times \frac{\text{weight}}{2.3 \times 10^{6}} = \text{value for area (m}^2\text{)}$	B1 C1 A1	**Allow** use of 10 for g (since estimate) **Allow ECF** for incorrect weight **Ignore** POT **Allow** one significant figure __**Examiner's Comments**__ A good proportion of the candidates scored full marks on this question. Some candidates found the total area rather than the area of one leg. A few candidates assumed that the stool had four legs.

					This question required candidates to estimate the mass or weight of an adult. In general, in this type of question a more generous mass is sensible. Candidates who did well on this question started by stating the mass (or weight) of an adult. Examiners allowed a mass between 50 kg and 150 kg. Candidates then often worked out the total area before working out the area of one of the legs. Some candidates did not correctly understand that 2.3 MPa was equal to 2.3×10^6 Pa. Some candidates incorrectly divided the stress by three. **Exemplar 4**  This candidate has clearly identified the average weight of an adult and then indicated how the weight of the adult is determined. The candidate has then clearly stated the equation for stress and shown their working for full marks. **AfL** Candidates should be encouraged to practise making estimates of physical quantities.
			Total	**3**	
14			**D**	1	
			Total	**1**	
15			**C**	**1**	
			Total	**1**	
16			(1 C =) (1) A s	C1	**Allow** alternative methods
			(1 J =) (1) kg m s^{-2} × m or (1) N = (1) kg m s^{-2}	C1	
			$V = \frac{\text{kg ms}^{-2} \times \text{m}}{\text{As}} = \frac{\text{kgm}^2\text{s}^{-2}}{\text{As}}$	M1	**Note** this mark is for clear substitution and working **Examiner's Comments** Some candidates were not clear on what was
			$\text{kg m}^2\text{A}^{-1}\text{s}^{-3}$	A0	

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>meant by base units. Most realised that the quantity of electric charge is measured in As. Weaker candidates had difficulty deriving work done.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>17</td><td></td><td>i</td><td>Similarity – same unit (AW)</td><td>B1</td><td>Allow ‘both defined as energy (transformed) per unit charge’ or ‘both defined as work done per unit charge’</td></tr>
<tr><td></td><td></td><td>i</td><td>Difference – For e.m.f, energy is transformed from chemical / other forms to electrical and for p.d., energy is transformed to heat / other forms from electrical</td><td>B1</td><td>Allow any pair from:
<table>
<tr><td>e.m.f.</td><td>p.d.</td></tr>
<tr><td>Energy (transformed) to electrical</td><td>Energy (transformed) from electrical or Energy (transformed) to heat /other forms</td></tr>
<tr><td>Charges gain energy</td><td>Charges lose energy</td></tr>
<tr><td>Work done on charges</td><td>Work done by charges</td></tr>
</table>
Examiner's Comments

Most candidates knew that e.m.f. and p.d. were both measured in volts (V). A small number of candidates thought that ‘volt’ was the same as ‘voltage’. This question benefitted those who taken time to revise thoroughly. The modal mark was one, but a significant number of candidates scored two marks for their flawless answers.</td></tr>
<tr><td></td><td></td><td>ii</td><td>$n = \dfrac{9.6 \times 10^{16}}{1.2 \times 10^{-6} \times 6.0 \times 10^{-3}}$ or $n = 1.3(3...) \times 10^{25}$ (m^{-3})

($I = Anev$)</td><td>C1</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>$0.003 = 1.2 \times 10^{-6} \times 1.33... \times 10^{25} \times 1.6 \times 10^{-19} \times v$</td><td>C1</td><td>Note Any subject for this equation</td></tr>
<tr><td></td><td></td><td>ii</td><td>$v = 1.2 \times 10^{-3}$ (m s^{-1})</td><td>A1</td><td>Allow 1 mark for $1.6(3) \times 10^{5}$ (m s^{-1}); $n = 9.6 \times 10^{16}$ used

Examiner's Comments

Almost all candidates were familiar with the equation $I = Anev$. However, only the top-end candidates realised that the number density of the charge carriers (electrons) had to be calculated from the number of electrons given and the volume of the resistor. The majority of candidates incorrectly assumed n to be 9.6×10^{16} m^{-3} when it should have been 1.3×10^{25} m^{-3}. Examiners awarded one mark for those</td></tr>
</table>

					candidates who arrived at the answer 1.6 × 10^5 m s^{-1} using the incorrect value of *n*.
			Total	**5**	
18	a		energy input = $mc\Delta\theta$ = 0.327 × 4200 × 80 = 110 kJ	C1 M1	Allow 0.3 kg in the calculation
			energy input = power × time	C1	
			time = 220 (s)	A0	
	b		Thermal losses to kettle and surroundings	B1	
			Lagging the kettle	B1	
			Cover to prevent evaporation	B1	
			Total	**6**	