

Mark scheme – Physical Quantities

Question			Answer/Indicative content	Marks	Guidance
1			Line of best fit drawn through the data points		Allow ± 2 . Not calculated through use of a single point.
			Gradient = 38	B1	Possible ECF from incorrect gradient
			($Ck \ln 2 = \text{gradient}$)	C1	Note: gradient of 40 gives 4.8×10^4 and gradient of 36 gives 4.3×10^4
			$1.2 \times 10^{-3} \times k \times \ln 2 = 38$	C1	Examiner's Comments
			$k = 4.6 \times 10^4 \text{ (}\Omega \text{ m}^{-1}\text{)}$	A1	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	$I = (v/4)(1/f) - k$	M1	Correct manipulation of equation must be shown
			Correct comparison with $y = mx + c$	A1	
		ii	large triangle used to determine gradient	B1	$\Delta x > 0.6 \times 10^{-3}\text{s}$
			gradient calculated correctly	B1	Expect between 80 and 82 (m s^{-1})
			$v = 320 \text{ (m s}^{-1}\text{)}$	B1	Allow 320 ± 20 ; allow ECF from an incorrect gradient
	b	i	Value of $1/F$ determined correctly from graph	C1	Allow values between $2.83 \times 10^{-3}\text{s}$ and $2.84 \times 10^{-3}\text{s}$
			$F = 350 \text{ (Hz)}$	A1	Allow only alternative methods which use values from line of best fit
		ii	$(100 (\Delta F/F) =) 100 \Delta v/v$	B1	
			$+ \frac{100 (\Delta I + \Delta k)}{(I + k)}$	B1	

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			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	$F = 0.050 \cos 40^\circ$ $F = 0.038$ (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) $d = 0.050 / m\omega^2 = 0.050 / 66.3 \times (3.5 \times 10^{-3})^2$ $d = 62$ (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 = $(-) 7.2 \times 10^{11}$ (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}) $KE = \frac{1}{2}mv^2 = 0.5 \times 810 \times (29.8 \times 10^3)^2$ $KE = 3.6 \times 10^{11}$ (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 = $(-) 3.6 \times 10^{11}$ (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) $\lambda = \ln 2/(88 \times 3.16 \times 10^7)$ (= $2.5 \times 10^{-10} s^{-1}$) ($A = \lambda N$); 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	$P = P_0 \exp(-\lambda t)$	C1	Allow formula in terms of N or A

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			$P = 470 \exp(-\ln 2 \times 100 / 88)$ $P = 210 \text{ (W)}$	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 <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A partial explanation using kinetic theory ideas and either a partial proof using formulae or a partial calculation <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) An attempt at either explanation or proof or calculation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	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 $= \frac{3}{2}pV = 1.5 \times 0.065 \times 1.0 \times 10^5 = 9.8 \text{ kJ}$ • At $T = 293\text{K}$, $N = pV/kT = 1.6 \times 10^{24}$ and $n = 2.7 \text{ moles}$ • At $T = 473\text{K}$, $N = 1.0 \times 10^{24}$ and $n = 1.7 \text{ moles}$

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					so we can show that NT (and/or nT) remain constant
			Total	6	
6	a	i	$(F = ma =) 190 \times 10^3 = 2.1 \times 10^5 \text{ a}$ $a = 0.90 \text{ (m s}^{-2}\text{)}$	M1 A0	$a = 0.905$ to 3 SF
		ii	$(v^2 = u^2 + 2as \text{ gives}) 36 = 2 \times 0.90 \times s$ $s = 20 \text{ (m)}$	C1 A1	Allow any valid suvat approach; allow ECF from (i) Note using $a = 1$ gives $s = 18\text{(m)}$
		iii	1 $P = Fv$ One correct calculation e.g. $F = 100 \times 10^3$ and $v = 42$ gives $P = 4.2 \times 10^6 \text{ (W)}$ $Fv = \text{constant}$ 2 $(P = VI = 4.2\text{MW so}) 4.2 \times 10^6 = 25 \times 10^3 \times I$ $I = 170 \text{ (A)}$	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 <i>or</i> correct calculation of Fv at <u>two</u> points (or more) Allow $P = 4\text{MW}$ or ECF from (iii)1 Expect answers between 160 - 170 (A)
	b	i	$R (= \rho L/A) = 1.8 \times 10^{-8} \times 1500 / 1.1 \times 10^{-4}$ $R = 0.25 \text{ (}\Omega\text{)}$	C1 A1	
		ii	$E = \sigma/\epsilon = T/A\epsilon \text{ (so } T = EA\epsilon\text{)}$ $T = 1.2 \times 10^{10} \times 1.1 \times 10^{-4} \times 0.013$ $T = 1.7 \times 10^4 \text{ (N) or } 17 \text{ (kN)}$	C1 C1 A1	or calculation of $\sigma = 1.56 \times 10^8 \text{ (Nm}^{-2}\text{)}$ or $T = 1.56 \times 10^8 \times 1.1 \times 10^{-4}$
			Total	13	
7		i	$R = 3000 + 1500$ $V = 12 \times 1500 / 4500 = 4.0 \text{ (V)}$	C1 A1	$R = 4500 \text{ (}\Omega\text{)}$ or $I = V/R = 12 / 4500 = 2.67 \text{ mA}$ $V_{1500} = 2.67 \text{ mA} \times 1.5 \text{ k}\Omega = 4.0 \text{ (V)}$
		ii	$V (= 12 \times 1500 / 1600) = 11.25 \text{ (V)}$ $\Delta V = 11.25 - 4.0 = 7.25 \text{ (V)}$	C1 A0	
			Total	3	
8		i	$E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{490 \times 10^{-9}}$ energy = $4.1 \times 10^{-19} \text{ (J)}$	C1 A1	Note answer to 3 SF is 4.06×10^{-19}

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		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			$h \rightarrow \text{J s} \quad / \quad h \rightarrow \text{N m s} \quad / \quad \text{J} \rightarrow \text{kg m}^2 \text{s}^{-2}$ base unit = $\text{kg m}^2 \text{s}^{-1}$	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 $4.8 \times 10^{-7} = k \times [7.8 \times (10^{-9})]^2$
			Total	4	
12			C	1	
			Total	1	
13			(Mass of adult =) 50 kg to 150 kg or $W = 500\text{N}$ to 1500 N Area = $\frac{\text{weight}}{2.3 \times 10^n}$ 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.

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					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 Estimate the minimum cross-sectional area A of one leg. <i>average adult mass = 60 kg</i> $\text{Stress} = \frac{\text{Force}}{\text{Area}}$ <i>weight = 60 x 9.81 = 588.6 N</i> $2.3 \times 10^6 = \frac{600}{A}$ <i>2.6 x 10⁻⁴ = 8.7 x 10⁻⁵</i> $A = 8.7 \times 10^{-5} \text{ m}^2$ [3] 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 (1 J =) (1) kg m s⁻² × m or (1) N = (1) kg m s⁻² $V = \frac{\text{kg ms}^{-2} \times \text{m}}{\text{kg m}^2 \text{A}^{-1} \text{s}^{-3}} = \frac{\text{kg m}^2 \text{s}^{-2}}{\text{As}}$	C1 C1 M1 A0	Allow alternative methods Note this mark is for clear substitution and working Examiner's Comments Some candidates were not clear on what was	

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					meant by base units. Most realised that the quantity of electric charge is measured in As. Weaker candidates had difficulty deriving work done.								
			Total	3									
17		i	Similarity – same unit (AW)	B1	Allow ‘both defined as energy (transformed) per unit charge’ or ‘both defined as work done per unit charge’								
		i	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	B1	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 ‘ <i>volt</i> ’ was the same as ‘ <i>voltage</i> ’. 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.	e.m.f.	p.d.	Energy (transformed) to electrical	Energy (transformed) from electrical or Energy (transformed) to heat /other forms	Charges gain energy	Charges lose energy	Work done on charges	Work done by charges
e.m.f.	p.d.												
Energy (transformed) to electrical	Energy (transformed) from electrical or Energy (transformed) to heat /other forms												
Charges gain energy	Charges lose energy												
Work done on charges	Work done by charges												
		ii	$n = \frac{9.6 \times 10^{16}}{1.2 \times 10^{-6} \times 6.0 \times 10^{-3}} \quad \text{or} \quad n = 1.3(3...) \times 10^{25} \text{ (m}^{-3}\text{)}$ $(I = Anev)$	C1									
		ii	$0.003 = 1.2 \times 10^{-6} \times 1.33... \times 10^{25} \times 1.6 \times 10^{-19} \times v$	C1	Note Any subject for this equation Allow 1 mark for $1.6(3) \times 10^5 \text{ (m s}^{-1}\text{)}$; $n = 9.6 \times 10^{16}$ 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 $9.6 \times 10^{16} \text{ m}^{-3}$ when it should have been $1.3 \times 10^{25} \text{ m}^{-3}$. Examiners awarded one mark for those								
		ii	$v = 1.2 \times 10^{-3} \text{ (m s}^{-1}\text{)}$	A1									

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