

Markscheme

November 2016

Physics

Higher level

Paper 2

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General Marking Instructions

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.
2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.
3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**
4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use RM™ Assessor annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate. Please do not allow these annotations to obscure the written material. Try to keep these to the margin of the scan as far as possible. (Ticks should however be at the point of award, cf 4.)
5. Personal codes/notations are unacceptable.
6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, use the “ZERO” annotation to award zero marks. Where a candidate has not attempted the part question, use the “SEEN” annotation to show you have looked at the question. RM™ Assessor will apply “NR” once you click complete.
7. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp “SEEN” on any additional pages that contain work not related to the QIG you are currently marking, or are blank or where the candidate has crossed out his/her work.
8. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the “CON” stamp.

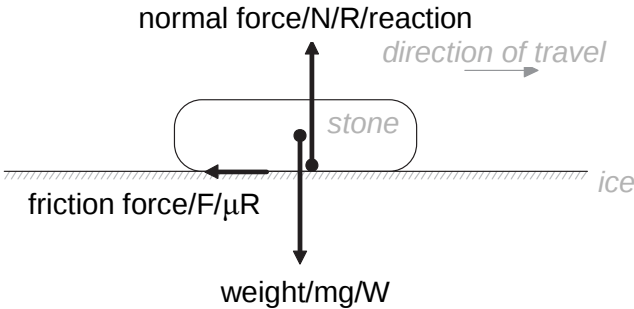
Subject Details: Physics HL Paper 2 Markscheme

Candidates are required to answer **all** questions. Maximum total **95 marks**.

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative wording is indicated in the “Answers” column by a slash (/). Either wording can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. “ECF acceptable” will be displayed in the “Notes” column.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.

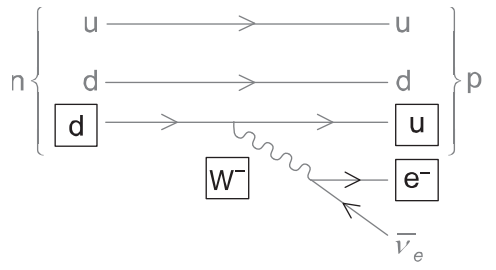
Question			Answers	Notes	Total
1.	a		determines component correctly / $15 \sin 50$ seen ✓ $s = \frac{(15 \sin 50)^2}{2 \times 9.81} = 6.7 \text{ «m» } \checkmark$ correct reasoning consistent with candidate data ✓	Allow method via $v = u + at$. Allow use of $g = 10 \text{ m s}^{-2}$, gives 6.6 m and 8.1 m. Allow [2 max] for use of $15 \cos 50$, gives 4.7 m and 6.2 m. Allow [1 max] (as MP2) if 13 m is obtained due to use of 15 m s^{-1} rather than $15 \sin$ or $15 \cos 50$. If no unit given, assume metre.	3
	b	i	$F = \frac{(0.058 \times 15)}{0.023} = 38 \text{ «N» OR } 37.8 \text{ «N» } \checkmark$	Do not penalise sf here. Working not required.	1
	b	ii	force of ball on racket is equal to force of racket on ball or is 38 N ✓ ball exerts force in opposite direction to force of racket on ball ✓	Do not accept “same force”. Allow ECF from force value in bi Accept “opposite force” for “in opposite direction”. Do not accept undefined references to “reaction” the direction of the forces must be clear.	2

Question			Answers	Notes	Total
2.	a		evidence that area under graph used OR use of mean velocity $\times$ time ✓ $\ll \frac{29.8 \times 2}{17.5} \gg = 3.41 \ll \text{ms}^{-1} \gg$ ✓	Award [2] for a bald correct answer. Award [1] for 1.70 ms^{-1}.	2
	b		ALTERNATIVE 1 $\ll \text{deceleration} \gg = \frac{3.41}{14.0} \ll = 0.243 \text{ ms}^{-2} \gg$ ✓ $F = 0.243 \times m$ ✓ $\mu = \frac{0.243 \times m}{m \times 9.81} = 0.025$ ✓ ALTERNATIVE 2 distance travelled after release = $23.85 \ll \text{m} \gg$ ✓ KE lost = $5.81m \ll \text{J} \gg$ ✓ $\mu_d = \frac{\text{KE lost}}{mg \times \text{distance}} = \frac{5.81m}{23.85mg} = 0.025$ ✓	Award [3] for a bald correct answer. Ignore sign in acceleration. Allow ECF from (a) (note that $\mu = 0.0073 \times$ candidate answer to (a)). Ignore any units in answer. Condone omission of m in solution. Allow $g = 10 \text{ N kg}^{-1}$ (gives 0.024).	3

Question		Answers	Notes	Total
	c	normal force, upwards, ignore point of application ✓ weight/weight force/force of gravity, downwards, ignore point of application ✓ friction/resistive force, to left, at bottom of stone, point of application must be on the interface between ice and stone ✓ 	Force must be labeled for its mark to be awarded. Blob at poa not required. Allow OWTTE for normal force. Allow N, R, reaction. The vertical forces must lie within the middle third of the stone. Allow mg, W but not “gravity”. Penalise gross deviations from vertical/horizontal once only. Allow F, μR. Only allow arrows/lines that lie on the interface. Take the tail of the arrow as the definitive point of application and expect line to be drawn horizontal. Award [2 max] if any force arrow does not touch the stone Do not award MP3 if a “driving force” is shown acting to the right. This need not be labelled to disqualify the mark. Treat arrows labelled “air resistance” as neutral. N.B: Diagram in MS is drawn with the vertical forces not collinear for clarity.	3

Question			Answers	Notes	Total
3.	a		mention of atoms/molecules/particles ✓ sum/total of kinetic energy and «mutual/intermolecular» potential energy ✓	<i>Do not allow “kinetic energy and potential energy” bald.</i> <i>Do not allow “sum of average ke and pe” unless clearly referring to total ensemble.</i>	2
	b	i	«intermolecular» potential energy/PE of an ideal gas is zero/negligible		1
	b	ii	THIS IS FOR USE WITH AN ENGLISH SCRIPT ONLY use of $T = \frac{PV}{nR}$ or $T = \frac{1.4 \times 21}{0.46 \times 8.31}$ ✓ 7.7 K ✓	<i>Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.</i> <i>Award [2] for a bald correct answer in K.</i> <i>Award [2 max] if correct 7.7 K seen followed by –265 °C and mark BOD. However, if only –265 °C seen, award [1 max].</i> <i>Do not penalise use of “K”</i>	2
	b	ii	THIS IS FOR USE WITH A SPANISH SCRIPT ONLY $T = \frac{PV}{nR}$ ✓ $T = \frac{1.4 \times 2.1 \times 10^{-6}}{0.46 \times 8.31}$ ✓ $T = 7.7 \times 10^{-6} \text{ K}$ ✓	<i>Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.</i> <i>Uses correct unit conversion for volume</i> <i>Award [2] for a bald correct answer in K.</i> <i>Finds solution. Allow an ECF from MP2 if unit not converted, ie candidate uses 21 m3 and obtains 7.7 K</i> <i>Do not penalise use of “K”</i>	2 max

Question			Answers	Notes	Total
	b	iii	«models used to» predict/hypothesize / lead to further theories ✓ explain / help with understanding / help to visualize ✓ simulate ✓ simplify/approximate ✓	<i>Response needs to identify two different reasons. (N.B. only one in SL).</i> <i>Do not allow any response that is gas specific. The question is couched in general, nature of science terms and must be answered as such.</i>	2 max

Question			Answers	Notes	Total
4.	a		charge: $-1e$ or negative or K^- ✓ strangeness: -1 ✓ baryon number: 0 ✓	Negative signs required. Award [2] for three correct answers, [1 max] for two correct answer and [0] for one correct answer.	2 max
	b		 correct symbols for both missing quarks ✓ exchange particle and electron labelled W or W^- and e or e^- ✓ arrows for both electron and anti-neutrino correct ✓	Do not allow W^+ or e^+ or β^+. Allow β or β^-. Allow ECF from previous marking point.	3

Question			Answers	Notes	Total
	c		decay products include an electron that has mass OR products have energy that has a mass equivalent OR mass/mass defect/binding energy converted to mass/energy of decay products ✓ «SO» mass C-14 > mass N-14 OR mass of n > mass of p OR mass of d > mass of u ✓	Accept reference to “lighter” and “heavier” in mass. Do not accept implied comparison, eg “C-14 has greater mass”. Comparison must be explicit as stated in scheme.	2

Question			Answers	Notes	Total
	d	i	number of C-14 atoms/nuclei are decreasing ✓ OR decreasing activity proportional to number of C-14 atoms/nuclei ✓ OR $A = A_0 e^{-\lambda t}$ so A decreases as t increases	<i>Do not allow “particles”</i> <i>Must see reference to atoms or nuclei or an equation, just “C-14 is decreasing” is not enough.</i>	1
	d	ii	$0.21 = (0.5)^n$ OR $0.21 = e^{-\left(\frac{\ln 2 \times t}{5700}\right)}$ ✓ $n = 2.252$ half-lives or $t = 12834$ «y» ✓ 13000 y rounded correctly to two significant figures: ✓	<i>Early rounding to 2.25 gives 12825 y</i> <i>Both needed; answer must be in year for MP3.</i> <i>Allow ECF from MP2.</i> <i>Award [3] for a bald correct answer.</i>	3

Question			Answers	Notes	Total
5.	a	i	minima = destructive interference ✓ at minima waves meet 180° or π out of phase ✓	Allow “crest meets trough”, but not “waves cancel”. Allow “destructive superposition” but not bald “superposition”. Allow similar argument in terms of effective path difference of $\frac{\lambda}{2}$. Allow “antiphase”, allow “completely out of phase” Do not allow “out of phase” without angle. Do not allow $\frac{n\lambda}{2}$ unless qualified to odd integers but accept $(n + \frac{1}{2})\lambda$	2
	a	ii	$\lambda = \frac{sd}{D}$ or $\lambda = \frac{12 \times 2 \times 7.2}{54} =$ or $\lambda = \frac{12 \times 7.2}{54} =$ seen ✓ $\lambda = \frac{12 \times 2 \times 7.2}{54} = 3.2$ «cm» ✓	Award [2] for a bald correct answer. Award [1 max] for 1.6 «cm» Award [2 max] to a trigonometric solution in which candidate works out individual path lengths and equates to $\frac{\lambda}{2}$.	2

Question		Answers	Notes	Total
	b	ALTERNATIVE 1 the component of the polarized signal in the direction of the receiving antenna ✓ is a maximum «when both are parallel» ✓ ALTERNATIVE 2 receiving antenna must be parallel to plane of polarization ✓ for power/intensity to be maximum ✓ ALTERNATIVE 3 refers to Malus' law or $I = I_0 \cos^2 \theta$ ✓ explains that I is max when $\theta = 0$ ✓ ALTERNATIVE 4 an electric current is established in the receiving antenna which is proportional to the electric field ✓ maximum current in receiving antenna requires maximum field «and so must be parallel» ✓	<i>Do not accept "receiving antenna must be parallel to transmitting antenna"</i>	2

Question			Answers	Notes	Total
	c	i	$I_0 = \frac{I}{\cos^2 \theta} \text{ or } \frac{12}{\cos^2 30} \text{ seen } \checkmark$ $1.6 \times 10^{-5} \text{ «W» } \checkmark$	Award [2] for bald correct answer. Award [1 max] for MP1 if $9 \times 10^{-6} \text{ W}$ is the final answer (I and I_0 reversed). Award [1 max] if cos not squared ($14 \mu\text{W}$). Units not required but if absent assume W.	2
	c	ii	$1.9 \times 10^{-4} \text{ «S» } \checkmark$		1

Question			Answers	Notes	Total
6.	a	i	mention of Doppler effect OR «relative» motion between source and observer produces frequency/wavelength change ✓ the reflected waves come from an approaching “source” OR the incident waves strike an approaching “observer” ✓ increased frequency received «by the device or by the car» ✓	<i>Accept answers which refer to a double frequency shift.</i> <i>Award [0] if there is any suggestion that the wave speed is changed in the process.</i>	3
	a	ii	the car is a moving “observer” and then a moving “source”, so the Doppler effect occurs twice OR the reflected radar appears to come from a “virtual image” of the device travelling at $2v$ towards the device ✓		1

Question			Answers	Notes	Total
	a	iii	ALTERNATIVE 1 $v = \frac{(3 \times 10^8) \times (9.5 \times 10^3)}{(40 \times 10^9) \times 2} = 36 \text{ «ms}^{-1}\text{»} \checkmark$ «36 > 28» so car exceeded limit $\checkmark$ ALTERNATIVE 2 reverse argument using speed limit. $\Delta f = \frac{2 \times 40 \times 10^9 \times 28}{3 \times 10^8} = 7500 \text{ «Hz»} \checkmark$ « 9500 > 7500» so car exceeded limit $\checkmark$	For both alternatives, allow ecf to conclusion if v OR Δf are incorrectly calculated. There must be a sense of a conclusion even if numbers are not quoted. There must be a sense of a conclusion even if numbers are not quoted.	2
	b		$x = \frac{31 \times 10^3 \times 1.22 \times 2.5 \times 10^{-2}}{9.3} \checkmark$ 100 «m» $\checkmark$	Award [2] for a bald correct answer. Award [1 max] for POT error. Award [1 max] for 83 m (omits 1.22).	2

Question			Answers	Notes	Total
7.	a		the «gravitational» work done «by an external agent» per/on unit mass/kg ✓ in moving a «small» mass from infinity to the «surface of» planet / to a point ✓	Allow definition in terms of reverse process of moving mass to infinity eg “work done on external agent by...”. Allow “energy” as equivalent to “work done” N.B.: on SL paper Q5(a)(i) and (ii) is about “gravitational field”.	2
	b	i	escape speed $v = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 4.87 \times 10^{24}}{6.05 \times 10^6}} \text{ or } 1.04 \times 10^4 \text{ m s}^{-1}$ or «1.1 x 1.04 x 10⁴ m s⁻¹» = 1.14 x 10⁴ «m s⁻¹» ✓ KE = «0.5 x 3500 x (1.1 x 1.04 x 10⁴ ms⁻¹)² =» 2.27 x 10¹¹ «J» ✓	Care with ECF from MP1. Award [1 max] for omission of 1.1 – leads to 1.88 x 10¹¹ m s⁻¹. Award [2] for a bald correct answer.	2
	b	ii	Velocity/speed decreases / projectile slows down «at decreasing rate» ✓ «magnitude of» deceleration decreases «at decreasing rate» ✓ velocity becomes constant/non-zero OR deceleration tends to zero ✓	Mention of deceleration scores MP1 automatically. Accept “negative acceleration” for “deceleration”. Must see “velocity” not “speed” for MP3.	3

Question			Answers	Notes	Total
	c	i	clear evidence that v in $v^2 = \frac{4\pi^2 R^2}{T^2}$ is equated to orbital speed $\sqrt{\frac{GM}{R}}$ OR clear evidence that centripetal force is equated to gravitational force OR clear evidence that a in $a = \frac{v^2}{R}$ etc is equated to g in $g = \frac{GM}{R^2}$ with consistent use of symbols ✓ substitutes and re-arranges to obtain result ✓ «$T = \sqrt{\frac{4\pi^2 R}{\left(\frac{GM}{R^2}\right)}} = \sqrt{\frac{4\pi^2 R^3}{GM}}$»	Minimum is a statement that $\sqrt{\frac{GM}{R}}$ is the orbital speed which is then used in $v = \frac{2\pi R}{T}$ Minimum is $F_c = F_g$ ignore any signs. Minimum is $g = a$. Allow any legitimate method not identified here. Do not allow confused algebra or spurious methods involving eg equations of shm etc	2

Question			Answers	Notes	Total
	c	ii	«$T = 365 \times 24 \times 60 \times 60 = 3.15 \times 10^7 \text{ s}$» $M = \left\langle \frac{4\pi^2 R^3}{GT^2} \right\rangle = \frac{4 \times 3.14^2 \times (1.5 \times 10^{11})^3}{6.67 \times 10^{-11} \times (3.15 \times 10^7)^2} \checkmark$ $2 \times 10^{30} \text{ «kg» } \checkmark$	Allow use of $3.16 \times 10^7 \text{ s}$ for year length (quoted elsewhere in paper). Condone error in power of ten in MP1. Award [1 max] if incorrect time used (24 h is sometimes seen, leading to $2.66 \times 10^{35} \text{ kg}$). Units are not required, but if not given assume kg and mark POT accordingly if power wrong. Award [2] for a bald correct answer. No sf penalty here.	2

Question			Answers	Notes	Total
8.	a	i	R_T decreases with increasing I OR R_T and I are negatively correlated ✓	<i>Must see reference to direction of change of current in first alternative.</i> <i>Do not allow "inverse proportionality".</i> <i>May be worth noting any marks on graph relating to 8bii.</i>	1
	a	ii	at 0.4 A: $V_R > V_T$ or $V_R = 5.6$ V and $V_T = 5.3$ V ✓ so $R_R > R_T$ because $V = IR$ / $V \propto R$ «and I same for both» ✓	Award [0] for a bald correct answer without deduction or with incorrect reasoning. Ignore any references to graph gradients. Both elements must be present for MP2 to be awarded.	2
	b	i	decreases OR becomes zero at X ✓		1
	b	ii	realization that V is the same for R and T OR identifies that currents are 0.14 A and 0.06 A ✓ $V = 2$ V OR 2.0 V ✓	Award [0] if pds 2.8 V and 3.7 V or 1.4 V and 2.6 V are used in any way. Otherwise award [1 max] for a bald correct answer. Explanation expected.	2

Question			Answers	Notes	Total
9.	a		direction indicated downwards, perpendicular to plates ✓	Arrows must be between plates but allow edge effects if shown. Only one arrow is required.	1
	b		$E = \frac{V}{d} = 55000 \text{ «Vm}^{-1}\text{»} \quad \checkmark$ $B = \text{«} \frac{55000}{5 \times 10^5} = \text{» } 0.11 \text{ «T»} \quad \checkmark$	ECF applies from MP1 to MP2 due to math error. Award [2] for a bald correct answer.	2
	c		ALTERNATIVE 1 magnetic force increases OR magnetic force becomes greater than electric force ✓ electron beam deflects “downwards” / towards S OR path of beam is downwards ✓ ALTERNATIVE 2 when v increases, the B required to maintain horizontal path decreases ✓ «but B is constant» so path of beam is downwards ✓	Do not apply an ecf from (a). Award [1 max] if answer states that magnetic force decreases and therefore path is upwards. Ignore any statement about shape of path Do not allow “path deviates in direction of magnetic force” without qualification.	2

Question			Answers	Notes	Total
10.	a	i	« $55.5 \times 14.6 \times 0.59$ » = 4.78×10^8 W ✓	<i>A unit is required for this mark. Allow use of $J s^{-1}$. No sf penalty.</i>	1
		ii	« $14.6 \times 2.75 \times 3.16 \times 10^7$ » = 1.27×10^9 «kg» ✓	<i>If no unit assume kg.</i>	1
		iii	CO ₂ linked to greenhouse gas OR greenhouse effect ✓ leading to «enhanced» global warming OR climate change OR other reasonable climatic effect ✓		2
		iv	internal energy of steam/particles OR KE of steam/particles ✓ «transfers to» KE of turbine ✓ «transfers to» KE of generator or dynamo «producing electrical energy» ✓	<i>Do not award mark for first and last energies as they are given in the question. Do not allow “gas” for “steam”. Do not accept bald reference to moving OR turning generator.</i>	2 max

Question			Answers	Notes	Total
	b	i	$I = 0.96 \times \left(\frac{25 \times 10^3 \times 3.9 \times 10^3}{330 \times 10^3} \right) \checkmark$ $= 280 \text{ «A» } \checkmark$	Award [2] for a bald correct answer to 2 sf. Award [1 max] for correct sf if efficiency used in denominator leading to 310 A or if efficiency ignored (e=1) leading to 300 A (from 295 A but 295 would lose both marks). Must show two significant figures to gain MP2.	2
		ii	higher V means lower I «for same power» $\checkmark$ thermal energy loss depends on I or $\propto I^2$ or is $I^2 R$ so thermal energy loss will be less $\checkmark$	Accept “heat” or “heat energy” or “Joule heating” for “thermal energy”. Reference to energy/power dissipation is not enough.	2
	c	i	«long» sides of coil AB/CD cut lines of flux OR flux «linkage» in coil is changed $\checkmark$ «Faradays law:» induced emf depends on rate of change of flux linked OR rate at which lines are cut $\checkmark$ emfs acting in sides AB/CD add / act in same direction around coil $\checkmark$ process produces an alternating/sinusoidal emf $\checkmark$	“Induced” is required Allow OWTTE or defined symbols if “induced emf” is given. Accept “induced” if mentioned at any stage in the context of emf or accept the term “motional emf”. Award [2 max] if there is no mention of “induced emf”.	3 max
		ii	$Blv = 0.34 \times 8.5 \times 10^{-2} \times 2 = 0.058 \text{ «V» } \checkmark$	Accept 0.06 V.	1
	c	iii	$160 \times (c)(ii) = 9.2 \text{ or } 9.3 \text{ or } 9.6 \text{ «V» } \checkmark$	Allow ECF from (c)(ii) If 80 turns used in cii, give full credit for cii x 2 here.	1

Question			Answers	Notes	Total
11.	a		reference to photon OR energy = hf or $= \frac{hc}{\lambda}$ ✓ violet photons have greater energy than red photons ✓ when $hf > \Phi$ or photon energy > work function then electrons are ejected ✓ frequency of red light < threshold frequency «so no emission» OR energy of red light/photon < work function «so no emission» ✓		3 max
	b	i	line with same negative intercept «–1.15 V» ✓ otherwise above existing line everywhere and of similar shape with clear plateau ✓	Award this marking point even if intercept is wrong.	2

Question			Answers	Notes	Total
	b	ii	$\frac{hc}{\lambda e} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9} \times 1.6 \times 10^{-19}} = 3.11 \text{ eV} \checkmark$ $3.10 - 1.15 = 1.96 \text{ eV} \checkmark$	Intermediate answer is $4.97 \times 10^{-19} \text{ J}$. Accept approach using f rather than c/λ. Award [2] for a bald correct answer in eV. Award [1 max] if correct answer is given in J ($3.12 \times 10^{-19} \text{ J}$).	2

Question			Answers	Notes	Total
	b	iii	«KE = qVs =» 1.15 «eV» OR 1.84×10^{-19} «J» ✓ adds 2.50 eV = 3.65 eV OR 5.84×10^{-19} J ✓	Allow ECF from MP1 to MP2. Must see units in this question to identify energy unit used. Award [2] for a bald correct answer that includes units. Award [1 max] for correct answer without units.	2