OCR | A-LEVEL PHYSICS | H556/01

Modelling physics

June 2024 exam series

MARK SCHEME

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GCE

Physics A

H556/01: Modelling physics

A Level

Mark Scheme for June 2024

Oxford Cambridge and RSA Examinations

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

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Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

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7. Award No Response (NR) if:
   - there is nothing written in the answer space

   Award Zero '0' if:
   - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

   Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
   If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. **Annotations**

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Annotation		Meaning
✓	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
✗	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in numerical answers only, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. **Penalised only once in the paper.**
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.

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Annotation		Meaning
XP	Wrong physics or equation	Used in numerical answers only, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

Annotation	Meaning
/	Alternative and acceptable answers for the same marking point
Reject	Answers which are not worthy of credit
Not	Answers which are not worthy of credit
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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12. **Subject Specific Marking Instructions**

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

M marks These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

A marks These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

C marks These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

B marks These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

SIGNIFICANT FIGURES

If the data given in a question is to 2 sf, then allow an answer to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

SECTION A

Question	Answer	Marks	Guidance
1	D	1	
2	C	1	
3	B or D	1	
4	C	1	
5	A	1	
6	B	1	
7	A	1	
8	C	1	
9	D	1	
10	B	1	
11	C	1	
12	D	1	
13	A	1	
14	C	1	
15	B	1	
	Total	15	

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SECTION B

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance
General rule: Only penalise 1sf if answer to more sf not seen

Question			Answer	Mark	Guidance
16	**a**	**i**	Curve starts at (0,0) with gradient decreasing to a maximum value 30 on vertical axis matching highest point of candidate's line	B1 B1	Accept horizontal asymptote NB ignore candidate's response after their line reaches 30 (m/s)
		ii	Resistive force increases (with speed) Zero net or zero resultant force	B1 B1	Allow drag / (air) resistance / friction for 'resistive force' Allow resistive force = component of weight down the slope NOT simply idea of resistive force = weight
		iii	Component of weight down slope = 9300 sin 5° Re-arrange to (k=)$F \div v^2$ (k=)810 ÷ 900 = 0.9...	M1 M1 A1	Allow 810 or 811 seen Allow substitutions for variables Mark is for substitution <u>and</u> candidate's value seen
	b		evidence of substitution of $F=kv^2$ into $P = Fv$ $v = (P \div k)^{1/3}$ v = 44 (m s^{-1})	C1 C1 A1	e.g. $P = kv^3$, $P = (kv^2)\,v$, etc Allow use of k = 1 which gives 42 Allow answer within range 36 to 53

Question			Answer	Mark	Guidance
	c		Power is proportional to the speed cubed / Max speed is proportional to the cube root of max power / power proportional to speed x kv^2	B1	
			Valid reference to the cube root of 2 increase in velocity for double power / Valid reference to factor of 8 increase in power for double the velocity	B1	NB cube root of 2 is 1.2599… e.g. 1.26 x 44 = 55 (m s^{-1})
			TOTAL	12	

Question			Answer	Mark	Guidance
17	**a**		**Net** force is proportional to rate of change of momentum	B1	Allow “equal to” for ‘proportional’ Allow use of resultant or total for net Allow symbols provided they are defined. NOT force = mass x acceleration
	b	**i**	Horizontal = 43 (.3) (m s^{-1}) Vertical = 25 (m s^{-1})	B1 B1	 ignore sign Allow answers in incorrect order for 1 mark MAX Allow H = 7.7 (m s^{-1}), V = -49.4 (m s^{-1}) 1 mark MAX
		ii	Correct application of N3L Plus ONE from: (Direction of) momentum of air has changed or direction of air flow has changed There is a force on the air (from the model)	B1 B1 B1	force on air is equal (and opposite) to force on model
		iii	$F = \frac{\Delta p}{\Delta t}$ *F* = 35 × 25 (divided by 1) *F* =880 (N)	C1 C1 A1	 ecf candidate’s vertical velocity in (i) Allow 875 Allow 870
			TOTAL	8	

Question			Answer	Mark	Guidance
18	**a**	**i**	0.99	A1	Award mark for all candidates as some centres may not have seen the erratum for this question.
		ii	Data plotted at 6.0, 0.99 within half a small square	B1	ecf from (a)(i) treat use of 0.81 from table as ecf if candidate has left 18 (a)(i) blank
			Two trendlines drawn	B1	NOT straight lines connecting data points NOT straight line(s) of best fit
			Clear indication that upper curve's data is during loading and that lower curve's data is during unloading	B1	e.g Correct arrow direction or label 'loading' on upper curve and correct direction arrow or label 'unloading' on lower curve.
		iii	Any TWO from:		
			Not a straight line / AW	B1	
			(hence) not directly proportional	B1	allow 'k / spring constant not constant' allow Hooke's Law should be (directly) proportional
			Correct reference to plastic deformation when unloaded	B1	e.g. Mention of line not passing through origin when unloaded

Question			Answer	Mark	Guidance
		iv 1	joule	B1	Not J; since **name** is required. Allow joules NB if more than one answer given, mark first answer as per rubric on page 3
		iv 2	(the area is) increase in thermal or in internal energy of the rubber reference to reduction in the energy of the object or in the force applied to the object or the force applied to the floor	B1 B1	ignore unqualified ‘energy’ or ‘work done’ allow change in work done on rubber between loading and unloading e.g. the energy absorbed by the rubber / not returned to the object e.g. energy dissipated as heat or energy not transferred back to KE e.g. The object will not bounce as high e.g. object less likely to be damaged because the force on object is smaller e.g. floor is less likely to be damaged because the force on the floor is smaller e.g. the larger the area between the curves the lower the damage caused

Question			Answer	Mark	Guidance
	b		Any TWO from pulley adds friction / the load values would no longer equal the weights Greater lengths being used will reduce (%) uncertainty Reference to pulley's suspension rope reduces h because it is not inextensible Larger range of h may make eye level more difficult Larger h makes effect of non-vertical ruler more prominent	 B1 B1 B1 B1 B1	ignore plastic deformation
			TOTAL	10	

Question			Answer	Mark	Guidance
19			**Level 3 (5–6 marks)** description and analysis, with an appropriate comment about accuracy *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)** Description and some graphical analysis and some comment about accuracy *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)** Incomplete description or analysis, or an appropriate comment about accuracy *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	NB – use of two slit interference formula is incorrect physics. Mark XP and treat description as incomplete **Indicative scientific points may include:** **Description** ● Angles or distances measured from central maximum ● Some method of measuring angle directly, e.g. protractor ● Measuring distances from grating to screen and from central maximum to others ● Description of maxima ● White screen or wall ● Recognition and mitigation of risk of injury to eye **Analysis** ● Graph of d sin theta against n with gradient lambda (or workable alternative) ● Conversion of lines per mm to distance between lines

Question			Answer	Mark	Guidance
					Accuracy ● Use large room to achieve large distances ● Large distance reduces relative uncertainty ● Measure distance between corresponding maxima and halve ● Use of trigonometry to convert measured distances into angles from the centre ● use spots either side of the centre ● change diffraction grating for smaller d so that maxima are more spaced out ● change diffraction grating for larger d so that there are more maxima (and so more points on the graph) ● darken the room
			TOTAL	6	

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Question			Answer	Mark	Guidance
20	**a**	**i**	Internal energy (of an ideal gas) is the sum of the (randomly distributed) kinetic energies of the particles	B1	Allow use of KE or E_k and atoms/molecules for particles. Ignore reference to PE (of particles)
		ii	evidence of $NkT = \frac{1}{3}Nm\underline{c^2}$ Manipulation to insert ½ to give $\frac{1}{2}mc^2 = 3/2\ kT$	M1 A1	
	b	**i**	(r.m.s. speed =) $\sqrt{\frac{310^2+370^2+440^2+550^2}{4}}$ r.m.s. speed evaluated as 427 (m s^{-1})	M1 A1	Not arithmetic mean 418. Treat as XP. Allow 729100 as evidence of summation of squares Allow mean squared speed = 182275 (m^2s^{-2}) Allow any candidate evaluation that rounds to or is 427 i.e. 426.93...
		ii	$\frac{1}{2}mc^2 = 3/2\ kT$ $\frac{1}{2}m \times 430^2 = 3/2 \times 1.38 \times 10^{-23} \times 290$ (molar mass = $6.02 \times 10^{23} \times 6.49 \times 10^{-26}$) molar mass = 0.039 (kg mol^{-1})	C1 C1 A1	allow $\frac{1}{2}Mc^2 = 3/2\ RT$ allow any valid rearrangement allow $\frac{1}{2}M \times 430^2 = 3/2 \times 8.31 \times 290$ allow m = 6.5… x 10^{-26} (kg) or $m = 6.7 \times 10^{-26}$ (kg) Using 427 m s^{-1} gives 0.0396 i.e. 0.040
	c	**i**	Energy transferred from electrical (energy) to internal (energy) or thermal (energy) of filament	B1	Allow power supply doing electrical work on filament

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Question			Answer	Mark	Guidance
			Energy transferred from filament to internal energy of gas (because) the (rate of) energy lost to the surroundings = the (rate of) energy transfer gained (by filament)	B1 B1	Allow heating of gas by conduction Allow description of Newton's Law of Cooling Allow heating of gas by radiation Allow reference to thermal equilibrium of any part or whole of lamp structure
		ii	(*P*/*T* = constant) $\frac{120}{2400} = \frac{p}{290}$ pressure = 14.5 (kPa)	C1 A1	 Allow 15 Allow 14
			TOTAL	13	

Question			Answer	Mark	Guidance
21	a	i	Estimate of λ_{max} between 440 and 470 nm (T =) 5800 x 500/460 = 6300 K i.e. candidate's value	M1 A1	Allow 2.9 million for 5800 x 500 Allow assumption of 6300 K, calculation of lambda (M1) and then confirmation on graph (A1) for 2 marks
		ii	$L = 4\pi r^2 \sigma T^4$ Correct substitution of values i.e. $2.3 \times 10^{29} = 4\pi r^2 \sigma 6300^4$ radius = $1.4(3) \times 10^{10}$ (m)	C1 C1 A1	
	b	i	$P = 7.0 \times 10^{-15} \div 0.11$ $I = 6.36 \times 10^{-14} / 1.0 \times 10^{-4} = 6.4 \times 10^{-10}$ (Wm^{-2})	M1 A1	
		ii	$L/4\pi r^2 = 6.4 \times 10^{-10}$ $r = (L \div (6.4 \times 10^{-10} \times 4\pi))^{0.5}$ $= 5.4 \times 10^{18}$ (m) ($\div 9.5 \times 10^{15}$ =) 560 light years	C1 C1 C1 A1	Allow use of 6×10^{-10} Allow alternative method: Finding intensity at star surface C1 Using ratio of intensities = square of ratio of (star radius / distance to earth) C1 Use of 6×10^{-10} for I gives 580 ly

Question			Answer	Mark	Guidance
	c		Any three from:		Check diagram for rewardable content
			There is a range/ ‘band’ in the luminosity values at 6300 K	B1	
			range of luminosity is between $L_\odot$ and about 10 $L_\odot$	B1	
			The uncertainty in the distance calculated = ½ the uncertainty in the luminosity AW	B1	
			Reference to Nu Persei not necessarily being on the main sequence	B1	
			TOTAL	14	

Question			Answer	Mark	Guidance
22	a	i	Period equal to one day/24 hours/rotational period of Earth Or Rotation in same direction as the rotation of the Earth (on its axis) Or Equatorial orbit Or radius of orbit is approx 42 000 km Or height of orbit above Earth's surface is approx 36 000 km Or zero velocity relative to Earth's surface	B1	NOT 'is in the same place in the sky'
		ii	Use of T=3600x24 (or 86,400 from data book) Substitution into $T^2 = \frac{4\pi^2}{GM}r^3$ i.e. $(86400)^2 = (4\pi^2/(G \times 6.0 \times 10^{24}))r^3$ $r = 4.2 \times 10^7$ (m)	C1 C1 A1	
	b	i	$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$ $$\frac{1}{2}mv^2 = \frac{1}{2}\frac{GMm}{r}$$	M1 A1	Allow omission of 'm' on both sides of equation (gravitational field strength = centripetal acceleration) Cancelling/rearrangement/identification of GMm/r as GPE
	b	ii	(Increase in) GPE = (-56 - -63 MJ =) 7(MJ) or (Increase in) KE = 0.5 x 56 = 28 (MJ) Sensible reasoning, e.g. 7+28 >30	M1 A1	 Allow **evaluation of total energy** of 35 (MJ)

Question			Answer	Mark	Guidance
22	c		**Level 3 (5–6 marks)** Correct calculations, and advantages and limitations discussed. *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)** Correct calculations and an advantages discussed or Correct calculations and a limitation discussed. *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)** Attempted calculations or a single correct calculation or incomplete explanations of advantages and/or limitations. *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	Use level of response annotations in RM Assessor Ignore general knowledge answers e.g. accidents, cost, politics Allow references to energy, energy per unit mass or potential as interchangeable Allow ecf from candidate's value for total energy per unit mass in orbit from (i.e. 35 MJ) 22bii or use of 30 (MJ) **Indicative scientific points may include:** **Calculations** ● (Minimum) additional KE from aircraft=26 kJ ● Additional GPE from aircraft = 100 kJ ● Additional KE from equatorial launch=110 kJ ● GPE calculated by mgh as an acceptable approximation ● (Without taking Earth's rotation into account,)KE at equator is about 4x aircraft KE ● GPE calculated from v_g = (-)GM/r ● Total energy = 0.5GM/r

Question			Answer	Mark	Guidance
					Advantages ● Aircraft launch provides KE and GPE ● Aircraft velocity will be higher than 230 depending on where the aircraft takes off. ● Less (rocket) fuel required ● Aircraft launch has similar/slightly larger energy to equatorial ● Equatorial launches can only happen in limited locations/aircraft launches can take place almost anywhere **Limitations** ● Aircraft launches only suitable for small satellites. ● Effects (for either) only significant for near earth orbits/low altitudes ● Either launch provides very small fraction (less than 1%) of the energy required
			TOTAL	14	

Question			Answer	Mark	Guidance
23	a		Difference in energy level = 4.84 (× 10^{-19}) (J) $\lambda = hc/4.84 \times 10^{-19}$ and 4.11×10^{-7} (m) seen	M1 A1	Accept (-.58 - (-5.42)) for 4.84 Accept E = hf to find f, followed by $\lambda = c/f = 4.11 \times 10^{-7}$ (m) seen Allow 4.104×10^{-7} (m) seen
	b	i	Dark lines are **absorption** lines / idea of photon absorption / idea of electrons absorbing energy / idea of electrons making transition to higher energy level (i.e. excitation) Caused by light passing through (cooler) stellar atmosphere or Earth's atmosphere	B1 B1	 Allow (cooler) gases/hydrogen (gas)
		ii	$\Delta\lambda / \lambda$ = 22/410 or 21/411 $v = 0.054c = 1.6(1) \times 10^{7}$ (m s^{-1})	C1 A1	 NB 21/411 gives 1.5×10^{7} (m s^{-1}) Any evidence of use of 432 as denominator of $\Delta\lambda / \lambda$ is XP zero marks
		iii	Big Bang / Expanding universe i.e. Hubble's Law / dark matter or dark energy / AW	B1	 ignore redshift ignore Doppler
			TOTAL	7	

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