

Markscheme

May 2022

Astronomy

















Standard level

Paper 2

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The following are the annotations available to use when marking responses.

Annotation	Explanation	Shortcut	Annotation	Explanation	Shortcut
	Correct point – 1 mark will be added to the score for each tick placed up to the maximum for the question part. Please make sure that the number of ticks = the number of marks			Does not answer question	
	Unclear			Answer acceptable	
	Omission mark			Power of 10 error	
	Arithmetic error			Indicates that the point has been noted, but no credit has been given or to confirm that an examiner has checked a sub-part of a question that has not been answered.	
	Alternative solution			Text box for comments – used for additional marking comments, it can be used in conjunction with a specific tick if that is appropriate. You might like to have a word document of regularly used comments that can be copied and pasted into the text box.	
	Benefit of the doubt			Dynamic; can be sized to highlight area	
	Contradiction			Dynamic; horizontal line that can be expanded	
	Error carried forward			Award 0 marks. 0 marks will be added to the marks panel when this annotation is stamped on the script.	

You **must** make sure you have looked at all pages. Please put the  annotation on any blank page, to indicate that you have seen it.

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) through RM™ Assessor, by e-mail or telephone – if through RM™ Assessor or by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader through RM™ Assessor or by e-mail at any time if they have any problems/queries regarding marking. For any queries regarding the use of RM™ Assessor, please contact emarking@ibo.org.

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 word is indicated in the “Answers” column by a slash (/). Either word 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.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.

Section A

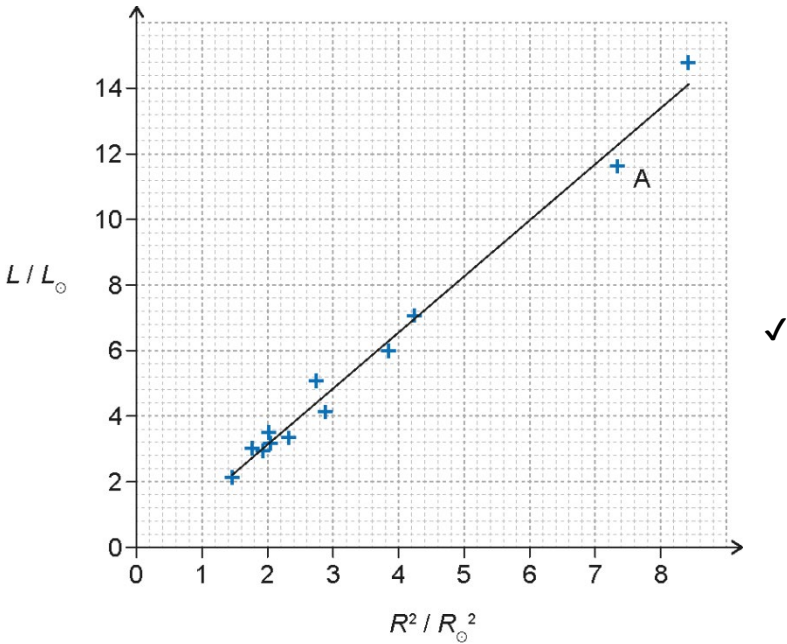
Question			Answers	Notes	Total
1.	a	i	$R = 3.8 \times 10^6 \text{ m} \checkmark$ $T = 2\pi \sqrt{\frac{(3.8 \times 10^6)^3}{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}} \text{ OR } 7.1 \times 10^3 \text{ s} \checkmark$	<i>Bald Correct Answer</i>	2
1.	a	ii	«in a circular orbit,» altitude/orbital radius does not change so PE is constant \checkmark «in the absence of friction,» speed/magnitude of velocity does not change so KE is constant \checkmark «so no energy is required»	<i>Do not accept velocity alone</i>	2
1.	b	i	$\frac{d_{Avior}}{d_{Alkaid}} = \frac{172}{33} \text{ OR } 5.2 \checkmark$ $\frac{L_{Avior}}{L_{Alkaid}} = 5.2^2 \text{ OR } 27 \checkmark$	<i>Bald Correct Answer</i>	2
1.	b	ii	<i>Avior:</i> calcium/iron/metals \checkmark <i>Alkaid:</i> hydrogen/helium \checkmark	<i>Ignore references to neutral or ionized. Do not allow molecules.</i>	2
1.	c		Alternative 1 idea that constellations are conventional and set boundaries in the sky \checkmark a galaxy/any celestial object can be seen within the limits of a constellation \checkmark Alternative 2 Orion covers part of the Milky Way where much dust and gas is found/where extinction is high \checkmark so it would be difficult to detect a galaxy «within Orion using visual observations» \checkmark		2

Question			Answers	Notes	Total
2.	a		<p>in the inner solar nebula/near the Sun, temperatures are high ✓</p> <p>matter with high condensation temperature was abundant OR there was more dust than ice/gas ✓</p> <p>dust grains merged/stuck together to form protoplanets ✓</p> <p>accretion led to the formation of the planets ✓</p>		3 max
2.	b	i	$E \ll \frac{L}{A} = 5.67 \times 10^{-8} \times 290^4 \gg = 401 \text{ «Wm}^{-2}\text{»} \checkmark$	Allow 400	1
2.	b	ii	<p>any text seen in cell next to infrared AND the other cells seen empty ✓</p> <p>carbon dioxide/water vapour/methane ✓</p>	<p>Allow chemical symbols</p> <p>Most likely answers, but others may be seen</p> <p>Award MP2 if the correct gas is seen anywhere on the table.</p>	2
2.	b	iii	glaciers recede/polar caps melt/decrease in rainfall/increase of sea levels ✓	Do not accept hotter weather or references to increases in temperature	1
2.	c		<p>«many» long period comets/icy objects are observed ✓</p> <p>their orbits are at any inclination with respect to the ecliptic ✓</p> <p>the aphelions of their orbits suggest the comets come from a spherical region at the edge of the Solar System ✓</p>	<p>MP1: allow asteroids</p> <p>MP2: allow orbits of the planets for ecliptic</p> <p>MP3: allow “furthest point” or equivalent expression for aphelion</p>	2 max

Question			Answers	Notes	Total
3.	a	i	$M = \frac{v^2 r}{G} \text{ OR } M = \frac{(5.9 \times 10^5)^2 \times 1.6 \times 10^{15}}{6.67 \times 10^{-11}} \checkmark$ $M = 4.2 \times 10^6 M_{\odot} \checkmark$	At least 2 significant figures for MP2	2
3.	a	ii	extinction by «interstellar» dust \checkmark		1
3.	a	iii	ALTERNATIVE 1 an accretion disk \checkmark composed of clouds of interstellar gas/molecular clouds \checkmark ALTERNATIVE 2 «Sagittarius A* is a strong» radio source \checkmark reference to synchrotron radiation OR maser OR water molecules \checkmark		2
3.	b		irregular/lrr \checkmark		1
3.	c	i	close encounter with another galaxy \checkmark gravitational/tidal forces exerted «between both galaxies» \checkmark changed the motions/orbits of stars in the galactic disk \checkmark		3
3.	c	ii	ALTERNATIVE 1 emission nebulae/ionized gases/interstellar clouds \checkmark seen as red regions along the spiral arms \checkmark ALTERNATIVE 2 interstellar dust/absorption nebulae \checkmark seen as dark lanes along the spiral arms \checkmark		2

Question			Answers	Notes	Total
4.	a	i	<p>ALTERNATIVE 1</p> $T_{\text{peak}} \ll \frac{2.9 \times 10^{-3}}{0.8 \times 10^{-6}} \gg = 3600 \text{ K} \checkmark$ <p>present-day temperature is 2.7 K \checkmark</p> <p>so curve does not correspond to present-day universe \checkmark</p> <p>ALTERNATIVE 2</p> $\lambda_{\text{today}} \ll \frac{2.9 \times 10^{-3}}{2.7} \gg = 1.1 \times 10^{-3} \text{ m} \checkmark$ <p>curve peaks at $\lambda = 0.8 \times 10^{-6} \text{ m} \checkmark$</p> <p>so curve does not correspond to present-day universe \checkmark</p>	<p><i>A clear conclusion must be seen for MP3.</i></p> <p><i>Allow use of 3 K</i></p>	3
4.	a	ii	values are the same in every direction \checkmark		1
4.	b	i	<p>the galaxy moves in space/with respect to the Sun \checkmark</p> <p>part of the redshift is due to the radial velocity of the galaxy \checkmark</p>		2
4.	b	ii	$d = \frac{cz}{H_0} \text{ OR } = \frac{3 \times 10^5 \times 0.017}{72} \text{ OR } = 71 \text{ «Mpc»} \checkmark$ <p>$d = 2.3 \times 10^8 \text{ light-years} \checkmark$</p>	<p><i>Accept a bald correct answer</i></p>	2
4.	c		dark energy \checkmark		1
4.	d		<p>observational/experimental evidence supports the theory \checkmark</p> <p>evidence has been critically checked/reviewed by other scientists \checkmark</p> <p>evidence is published in scientific journals \checkmark</p> <p>theory has been confronted against other models/theories \checkmark</p>		1 max

Section B

Question			Answers	Notes	Total
5.	a	i	$2.7 R_{\odot} \checkmark$		1
5.	a	ii	<p>x corresponds to R^2 and y corresponds to $L \checkmark$</p> <p>$y = kx$ OR $L = k R^2$ OR variables are <u>directly</u> proportional \checkmark</p> <p>$k = T^4$ where T is the temperature in units of solar T</p> <p>OR</p> <p>$k = 4\pi\sigma T^4$ is <u>constant</u> \checkmark</p>	<p>MP1: variables identified</p> <p>MP2: direct proportionality</p> <p>MP3: relates k with T. Condone omission of $4\pi\sigma$ in the second alternative.</p>	3
5.	a	iii		Do not penalize lines that are extended to the origin.	1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	a	iv	slope = 1.7 ✓ $\frac{T}{T_{\odot}} = \sqrt[4]{1.7} = 1.14 \quad \checkmark$ $T \ll 1.14 \times 5778 \gg = 6600\text{K} \quad \checkmark$	Measured slopes may differ. Check work.	3
5.	b	i	$p \ll \frac{1}{4.5 \times 10^{-2}} \gg = 22.2 \text{ «pc»} \quad \checkmark$ $d \ll 22.2 \times 3.26 \times 9.46 \times 10^{15} \gg = 6.8 \times 10^{17} \text{ «m»} \quad \checkmark$	At least 2 significant figures on final answer.	2
5.	b	ii	«angular diameter in radians =» $2.4 \times 10^{-9} \text{ «rad»} \quad \checkmark$ physical diameter = $2.4 \times 10^{-9} \times 6.8 \times 10^{17} = 1.6 \times 10^9 \text{ «m»} \quad \checkmark$ radius = $1.2 R_{\odot} \quad \checkmark$	ECF from (b)(i). Bald Correct Answer	3
5.	b	iii	$R^2 = 1.44 \quad \checkmark$ $L \sqcup 2.2 - 2.6 L_{\odot} \quad \checkmark$	Depending on fit. ECF from (b)(ii).	2
5.	c	i	from the Sun's formation/primordial ✓		1
5.	c	ii	Helium is a product of the pp chain/H fusion ✓ as it does not fuse, it has accumulated over time ✓		2
5.	c	iii	after H-shell burning begins ✓		1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	d		<p>«models help scientists to»</p> <p>simulate condition within the system/phenomenon ✓</p> <p>better understand the system/phenomenon ✓</p> <p>visualise the behaviour of variables ✓</p> <p>confront the theoretical predictions/hypothesis with the observations/data ✓</p>		1 max
