Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2023

Astronomy

Standard level

Paper 2

10 pages

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 <u>underlined</u> 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	$\frac{b_s}{b_{ph}} = \frac{L_s}{L_{ph}}$ ***OR*** assume the sunspot ***AND*** the photosphere are at the same distance ✓ $= \left(\frac{4.2 \times 10^3}{5.77 \times 10^3}\right)^4$ ***OR*** assume sunspot/photosphere obeys Stefan's law ***OR*** behaves like a blackbody ✓ = 0.28 ✓	*For the final result at least two significant figures are required.* *Allow rounding of solar temperature to 5800 to yield 0.27.*	**3**
1.	a	ii	the number of sunspots is lowest «in the 11-year cycle» ✓		**1**
1.	a	iii	***Alternative 1*** sunspots are linked to the solar magnetic field ✓ the magnetic field lines exit from one member «of the pair» and enter into the other member ✓ ***Alternative 2*** sunspots behave like magnets ✓ one member «of the pair» has north polarity and the other member has south polarity ✓	*Accept a clearly drawn and labelled drawing for MP2 (either alternative).*	**2**
1.	b	i	any value in the range 4300 – 4600 K ✓		**1**
1.	b	ii	arrow starts from (5700 – 5800; 1) ✓ points towards the upper right region of the diagram: T < 5000; L > 10 ✓	*Allow straight or curved arrows.*	**2**

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Question			Answers	Notes	Total
1.	c		nuclear fusion/burning of helium «to produce carbon» ✓ hydrogen fusion/burning in a shell «surrounding the nucleus» ✓		2

2.	a	i	the orbits lie in «about» the same plane ***OR*** the orbits are «nearly» circular/elliptical ***OR*** the planets orbit the Sun in the same direction/sense ✓		1
2.	a	ii	gravitational forces made the matter/gas in the nebula contract ✓ most matter concentrated at the center of the nebula ***OR*** formed the protosun ✓ the rest formed a «flat» disk ✓ the planets formed by gravitational contraction/clumping of material in the disk ***OR*** reference to protoplanets ✓		3 max
2.	b	i	the process that separates the interior of a planet in layers ✓ of different density ***OR*** composition ✓	*For MP1 allow naming of 2 or more layers (eg: core and crust)*	2
2.	b	ii	heating from gravitational contraction ***OR*** heating from radioactive decay ✓ high density/heavier materials tend to sink ***OR*** low density/lighter materials tend to float ✓		2
2.	b	iii	waves change speed/direction when crossing layer boundaries ✓ frequencies/time arrival of waves measured at seismic stations ✓ location of layer boundaries are found from seismograph/seismic wave measurements ✓	*For MP1 allow reference to reflection/refraction*	2 max

Question			Answers	Notes	Total
3.	a	i	Black hole ✓		1
3.	a	ii	$d = 1.1 \times 10^{-4} \times 3.2 \times 10^{3}$ ✓ $d > 3.5 \times 10^{5}$ «pc» ✓	*For MP1 allow ECF.* *For MP2 inequality must be seen in symbols or words.*	2
3.	a	iii	reference to accretion disk ✓ particles «in the accretion disk» are accelerated to relativistic speeds/energy ✓ the disk reaches a very high temperature ✓ frictional forces/thermal losses are converted to photons/electromagnetic radiation ✓	*For MP4 allow other reasonable mechanisms.*	3 max
3.	a	iv	«most» quasars are at great distances so the parent galaxy is faint ***OR*** has a small «angular» size ✓ the quasar/accretion disk is much/hundreds of times more luminous than the rest of the galaxy ✓		2
3.	b		«to help readers» … know the source of the data ✓ … know the source of relevant theories/ideas/techniques used ✓ … check the validity of the research ✓ … understand how ideas evolved/changed ✓ to acknowledge the work of others ✓	*Allow other reasonable ideas.*	1 max
3.	c		star-forming regions ***OR*** protostars ✓ high-luminosity stars ✓ bright emission nebulae ✓ clouds of warm dust ***OR*** dust that radiates in the infrared ✓		2 max

Question			Answers	Notes	Total
4.	**a**	**i**	the average amount of mass per unit volume ✓ of mass/matter ***AND*** energy/radiation within the universe ✓		**2**
4.	**a**	**ii**	a flat geometry ✓		**1**
4.	**a**	**iii**	inflation is a rapid expansion of space soon after the Big Bang ✓ space increased by a factor of 10^{50} during the inflationary period ✓ the expansion was so great that made the geometry nearly flat ✓	*Allow equivalent words for rapid.*	**3**
4.	**b**		for each galaxy, its position in the sky is measured/recorded **«**from images**»** ✓ the distance to each galaxy is measured from Doppler shift/Hubble law/Supernova light curve/Cepheid light curve ✓	*Allow other valid methods*	**2**

Question			Answers	Notes	Total
5.	a	i	a smooth fit line seen through the points in the graph ✓ $d = \sqrt{\frac{5.0\times10^{9}\times3.8\times10^{26}}{4\times\pi\times5.3\times10^{-12}}}$ ***OR*** $= 1.7\times10^{23}$ **«**m**»** ✓ $=$ «$\frac{1.7\times10^{23}}{9.46\times10^{15}} =$ » 1.8×10^{7} **«**light-years**»** ✓	*Bald correct answer*	**3**
5.	a	ii	***Alternative 1*** supernovae are much more luminous than cepheid variables ✓ so supernovae can be observed at greater distances ✓ thus, supernovae are better **«**indicators of distance**»** for distant galaxies ✓ ***Alternative 2*** not all galaxies may produce a supernova **«**in our time**»** ✓ cepheids are more common/frequently observed ✓ so cepheids are better **«**indicators of distance**»** for nearby galaxies/when no supernovae are detected ✓	*OWTTE*	**3**
5.	b		amateurs can learn techniques/how to do useful observations **«**with their equipment**»** ✓ observational errors can be estimated for **«**any type of submitted**»** data ✓ data from many amateurs can be averaged to reduce observational errors ✓ amateur clubs/communities can help filter/process data before submitting them to professionals ✓	*Allow other reasonable answers.*	**1 max**
5.	c	i	**«**barred**»** spiral ***OR*** S**«**A**»«**B**»** ✓ a ***OR*** ab ***OR*** b ✓	*For MP2: No ECF. Must see lowercase letters. Ignore other annotations.*	**2**
5.	c	ii	clouds of dust ✓ obscuring the stars/bright material within the disk/spiral arms ✓		**2**

(continued...)

Question			Answers	Notes	Total
5.	**d**	**i**	evidence that graph was used (6.0 kpc; 190 kms^{-1}) ***OR*** $R =$**«**$6 \times 10^3 \times 3.26 \times 9.46 \times 10^{15} =$**»** 1.9×10^{20} **«**m**»** ✓ $M = \frac{{v_{\text{orb}}}^2 \times R}{G} = \frac{(1.9 \times 10^5)^2 \times 1.85 \times 10^{20}}{6.67 \times 10^{-11}}$ ✓ $M = \frac{1.0 \times 10^{41}}{1.99 \times 10^{30}} = 5.0 \times 10^{10}$ **«***M*☉**»** ✓	*Allow values in the range 180–200 kms^{-1}, to yield 4.5 to 5.6 × 10^{10} $M_☉$.*	**3**
5.	**d**	**ii**	predicted/keplerian velocity is smaller than the measured velocity **«**at a given radius, not too near the nucleus of the galaxy**»** ✓ mass contained within *R* is proportional to velocity **«**squared**»** ✓ **«**thus, mass must be larger**»**	*For MP2 allow formula with symbols defined.*	**2**
5.	**e**	**i**	^2_1H ***OR*** ^2_1D ✓		**1**
5.	**e**	**ii**	$m = \frac{3.84 \times 10^{26}}{(3 \times 10^8)^2} = 4.3 \times 10^9$ **«**kg**»** ✓		**1**
5.	**e**	**iii**	$M = 4.3 \times 10^9 \times 4.6 \times 10^9 \times 365 \times 86400$ **«**$= 6.23 \times 10^{26}$ kg**»** ✓ fractional mass $= \frac{6.23 \times 10^{26}}{1.99 \times 10^{30}}$ **«**$\times 100 =$**»** ***OR*** 3.1×10^{-4} ***OR*** 0.031 % ✓	*For MP2: at least 1 extra significant digit for result.*	**2**