

Markscheme

May 2019

Astronomy

Standard level

















Paper 2

13 pages

This markscheme is **confidential** and for the exclusive use of examiners in this examination session.

It is the property of the International Baccalaureate and must **not** be reproduced or distributed to any other person without the authorization of the IB Global Centre, Cardiff.

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		<p>ALTERNATIVE 1</p> <p>$T = 8600 \text{ «K» } \checkmark$</p> <p>$\frac{T}{T_{\odot}} = 1.5 \checkmark$</p> <p>$R = \sqrt{\frac{20}{1.5^4}} = 2.0 R_{\odot} \text{ OR } 1.4 \times 10^9 \text{ «m» } \checkmark$</p> <p>ALTERNATIVE 2</p> <p>$T = 8600 \text{ «K» } \checkmark$</p> <p>$R^2 = \frac{20 \times 3.8 \times 10^{26}}{(4\pi \times 5.67 \times 10^{-8} \times 8600^4)} \checkmark$</p> <p>$R = 1.4 \times 10^9 \text{ «m» OR } 2.0 R_{\odot} \checkmark$</p>	<p><i>For Alternative 1:</i></p> <p><i>For MP1, accept values between 8400–8800 K.</i></p> <p><i>For MP2, ECF from MP1.</i></p> <p><i>For MP3, 1.9–2.1 depending on T.</i></p> <p><i>For Alternative 2:</i></p> <p><i>For MP1, accept values between 8400–8800 K.</i></p> <p><i>For MP2, correct substitution for MP2.</i></p> <p><i>For MP3, BCA with any alternative.</i></p>	3
1.	b		<p>«the spectra of» A-type stars have more absorption lines «than the spectra of M-type stars»</p> <p>OR</p> <p>H lines are stronger in A stars «than in M stars»</p> <p>OR</p> <p>lines of heavy elements/metals/molecules are weaker in A stars «than in M stars» \checkmark</p>	<p><i>Accept converse arguments for M stars.</i></p> <p><i>Accept H is strong in A stars <u>and</u> weak in M stars.</i></p> <p><i>Accept any examples of heavy elements (carbon or heavier), if present for MP3.</i></p>	1

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	c		light from the star's <u>hot</u> interior reaches its photosphere ✓ gas absorbs radiation of certain energy values/frequencies/wavelengths ✓ electrons in atoms are excited to upper energy levels ✓ the original radiation is re-emitted in other frequencies/directions ✓ thus, less of the original energy is detected ✓	<i>Allow atmosphere instead of photosphere.</i>	3 max
1.	d		after H is depleted in the core OR when He fusion begins in the core ✓ the star will become a red giant OR the star will have larger radius ✓	<i>Treat references to intermediate processes as neutral.</i>	2
1.	e		white dwarf OR black dwarf ✓	<i>Do not allow dwarf or brown dwarf.</i>	1

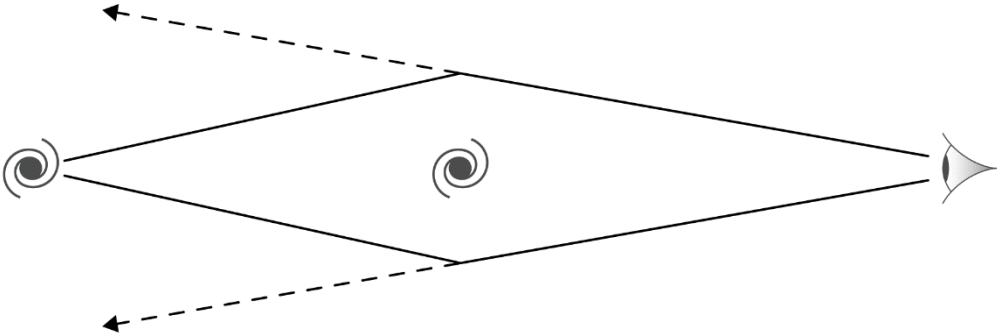
Question			Answers	Notes	Total
2.	a	i	<p>«kinetic energy of meteorite into» heat/thermal energy dissipated in surroundings OR «kinetic energy of meteorite into» kinetic energy of ejected material OR «kinetic energy of meteorite into» chemical/internal energy of surrounding rocks ✓</p>	<i>Candidates must state where the energy goes (eg: just “heat” does not score)</i>	1
2.	a	ii	<p>$v^2 = \frac{2 \times 1 \times 10^{23}}{3 \times 10^{14}}$ ✓ $v = 2.6 \times 10^4$ «ms⁻¹» ✓</p>	<p>Allow BCA Accept 1 or more SF</p>	2
2.	b		<p>dust/debris released into high atmosphere ✓ blocking the Sun for a long time/months OR less sunlight reaching the surface of the Earth ✓ vegetation became scarce and thus animals/species died OR food chain was interrupted ✓</p>	<i>Accept any valid specifics (eg: nuclear winter, acid rain)</i>	3
2.	c		<p>«meteorites come from» asteroids «which» are believed to be remnants from the solar system formation ✓ meteorite interiors suffer little/no transformations «after falling» ✓ ages «of rocks contained within meteorites» are measured using radiometric/radioactive dating ✓</p>		2 max

(continued...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	d		<p>«smaller» meteorites destroyed in atmosphere upon entry ✓</p> <p>erosion by air/water ✓</p> <p>erosion by plants/living organisms ✓</p> <p>surface changes from earthquakes/volcanoes ✓</p> <p>much of the surface covered by water ✓</p>	<p><i>For MP2, erosion by air and water scores [1].</i></p>	2 max

Question			Answers	Notes	Total
3.	a	i	population I OR disk ✓		1
3.	a	ii	open clusters have fewer stars «than globular clusters» ✓ OC have a greater proportion of blue/hot Main Sequence stars «than globular clusters» ✓ «generally/most» OC have a smaller proportion of red giants/white dwarfs «than globular clusters» ✓ stars in OC are younger «than stars in GC» ✓	<i>For MP1, accept converse arguments in terms of globular clusters.</i>	2 max
3.	b	i	line with a smooth, decreasing curve ✓ with a decreasing gradient ✓	<i>Allow any start/end point. Ignore any initial part to the curve under 3000 pc. A fit line scores 0.</i>	2
3.	b	ii	velocities are higher than expected with all/most mass concentrated «in the nucleus/halo/main body of the galaxy» OR the visible mass is not enough to explain the observed velocities ✓ there must be an additional force/acceleration «acting on the stars» ✓ dark matter provides the additional mass required «to fit the data» ✓	<i>This is a “Show that” question. Do not award a bold MP3 unless there is some previous justification.</i>	3
3.	c		by determining the distance to globular clusters/Cepheid variables/RR Lyrae ✓ they have a spherical distribution ✓ the centre of this distribution was interpreted as the centre of the Galaxy ✓		3

Question			Answers	Notes	Total
4.	a		<p>a star near the solar disk was observed «during the eclipse» ✓</p> <p>the position of the star «near the Sun» was compared with its known position ✓</p> <p>the starlight path changed due to the gravitational field of the Sun ✓</p> <p>the star appeared displaced as predicted «by General Relativity» ✓</p>		3 max
4.	b		<p>at least one light-ray bent in the correct direction ✓</p> <p>two rays extended away from observer ✓</p> <p>two blobs OR arrow points to show where lensed image is ✓</p>  <p>Distant galaxy Near galaxy Observer</p>		3
4.	c		<p>clusters of galaxies aligned in chains/filaments ✓</p> <p>voids/empty regions within/surrounding superclusters ✓</p> <p>reference to the Big Wall ✓</p>		1 max
4.	d		<p>the speed of light is finite/limited ✓</p> <p>thus, it takes time for light from distant objects to arrive to Earth ✓</p>		2

Section B

Question			Answers	Notes	Total
5.	a	i	<p>straight line showing a balanced fit ✓</p> $z = \frac{1.8 \times 10^4}{3.0 \times 10^5} = 0.06 \quad \checkmark$ <p>appropriate reading from graph ✓</p>	<p>Accept 240 to 250 Mpc.</p> <p>Do not ECF from MP2.</p>	3
5.	a	ii	<p>approaching galaxies have negative redshifts ✓</p> <p>nearby galaxies have a «very» small cosmological redshift ✓</p> <p>thus, a fast approaching galaxy has a negative redshift</p> <p>OR</p> <p>the galaxy's own radial velocity is greater than the velocity due to the expansion of the universe</p> <p>OR</p> <p>we only observe the true motion of the galaxy ✓</p>	<p>Accept $z = \frac{V_r}{c} < 0$.</p> <p>OWTTE – Candidates must recognize that redshift comes also from galaxies moving relative to each other; not just from the cosmic expansion.</p> <p>Accept reference to peculiar velocity.</p>	3
5.	a	iii	<p>gradient of fit line found</p> <p>OR</p> <p>use of two data points in graph ✓</p> $H = 3 \times 10^5 \times \text{gradient} = 75 \text{ km s}^{-1} \text{ Mpc}^{-1} \quad \checkmark$	<p>Look for evidence of use of graph to award MP1.</p> <p>Allow ECF from MP1.</p> <p>A BCA of 72, as given in booklet, scores 0.</p>	2

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	a	iv	$\frac{L_B}{L_A} = \frac{(b_B \times d_B)^2}{(b_A \times d_A)^2} \checkmark$ <p>simplify b</p> <p>OR</p> <p>state b_A and b_B are equal \checkmark</p> <p>from graph, $d_A = 200\text{Mpc}$ and $d_B = 450\text{Mpc}$ \checkmark</p> $= \left(\frac{450}{200}\right)^2 = 5.1 \checkmark$	Allow MP3 and MP4 for a BCA with more than 2 SF.	4
5.	b	i	<p>diameter in cm or mm measured \checkmark</p> <p>diameter (") = $1.1 \times \text{diameter (mm)}$ \checkmark</p> <p>diameter (rad) = diameter (") $\times \frac{\pi}{180.3600}$ \checkmark</p> <p>diameter (pc) = $21 \times 10^6 \times \text{diameter (rad)}$ \checkmark</p>	<p>Use of parallax formula denies MP3 and 4.</p> <p>Allow a range of 75–85 mm.</p> <p>Value may vary with printed dimensions.</p>	3 max
5.	b	ii	Acceptable answers: Sa/Sb/Sab/SBa/SBb/SBab \checkmark	Ignore other notations in the type (eg: Sb(s) scores 1).	1
5.	b	iii	<p>spiral arms tightly bound \checkmark</p> <p>bright/relatively large nucleus \checkmark</p>		2

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	c		international cooperation among scientists ✓ collaboration from amateur astronomers/organizations ✓ use of automatic/robotic telescopes/sensors/data analysis tools ✓ outreach collaborative programs «citizen science, community science, volunteer work, etc» ✓ use of classification schemes ✓	<i>NOS question. Do not allow discussions focusing <u>only</u> on galaxies.</i>	2 max
