Markscheme

May 2018

Astronomy

Standard level

Paper 2

14 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		NAQ	Does not answer question	
?	Unclear		OK	Answer acceptable	
λ	Omission mark		POT	Power of 10 error	
AEr	Arithmetic error		SEEN	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.	
ALT	Alternative solution		T	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.	
BOD	Benefit of the doubt		⬯	Dynamic; can be sized to highlight area	
CON	Contradiction		▭	Dynamic; horizontal line that can be expanded	
ECF	Error carried forward		0	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 SEEN 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**		most asteroids lie in the asteroid belt **OR** most asteroids lie in / close to the plane of the ecliptic ✓ most comets lie in Kuiper Belt / Oort Cloud / farther than Neptune **OR** most comets do not lie along a preferred orbital plane ✓	*Treat references to elliptical paths or other non-location answers as neutral.*	**2**
1.	**b**	**i**	$r = \dfrac{GM}{v^2}$ **OR** $r = 6.67 \times 10^{-11} \dfrac{1.99 \times 10^{30}}{(17 \times 10^3)^2}$ ✓ $r = 4.6 \times 10^{11}$ «m» ✓	*Accept other appropriate units.* *3 s.f acceptable, but not 1 or 4+*	**2**
1.	**b**	**ii**	$T = 2\pi . \dfrac{4.6 \times 10^{11}}{17 \times 10^3}$ ✓ $T = $ «1.7×10^8 s» $= 5.4$ «years» ✓ **OR** $T^2 = \left(\dfrac{4.6 \times 10^{11}}{1.5 \times 10^{11}} \right)^3$ ✓ $T = 5.4$ «years» ✓	*Award [1 max] for result in s or incorrect conversion.*	**2 max**
1.	**b**	**iii**	increased ✓ decreased ✓		**2**

| 1. | c | | at perihelion it is closer to the Sun ✓

the force of gravity is greater at perihelion ✓

«force of gravity» is a centripetal force / is proportional to velocity ✓

«therefore velocity is greater» | *Just a mention of KE not enough since gravity is not considered, but mention of gravitational PE as well is fine since this indicates the significance of gravity*

Using the full form (with "G") of Kepler's 3rd law is acceptable since the role of gravity is also clear from this | **3** |

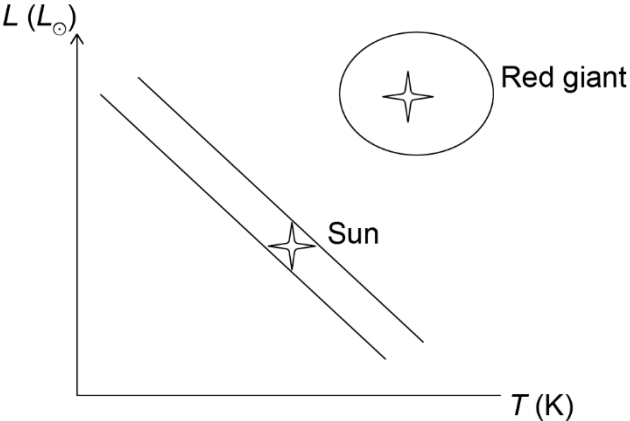| 2.	a		«strong» volcanic activity / lava flooding «by volcanoes» ✓ lack of «impact» craters «on its surface» ✓		**1 max**
2.	b		tidal forces are stronger than the force of gravity ✓ required to hold the particles together ✓	*Answers relating to the Roche Limit also acceptable for full marks.*	**2**
2.	c		nuclei decay to more stable nuclei/isotopes *OR* the number of radioactive nuclei / particles ejected decrease with time ✓ energy «from particles» transferred to the surrounding material ✓ fewer particles means less energy transferred «as heat» ✓ «therefore, lower temperature»	*Accept heat.*	**3**
2.	d		«planets have several» layers of different composition ✓	*The concept of layers is key to the answer, but talking about density differentiation without reference to layers is also OK*	**1**
2.	e		the average density of Earth is larger than the density of its surface layers ✓ thus its interior must have a larger density on average ✓ which rules out layers of air and water ✓ *OR* seismic waves propagate through the interior of Earth ✓ wave speed depends on the composition of the materials ✓ observations are inconsistent with a hollow planet / consistent with layers of rocky material ✓	*Accept one or the other, but not a mix.*	**3 max**

3.	a		quasars have a star-like appearance ✓ features surrounding the quasar are very faint «except on larger telescopes» ✓		**1 max**
3.	b		$z = «\dfrac{v}{c}» = \dfrac{Hd}{c}$ ✓ $d = 3 \times 10^5 \cdot \dfrac{0.19}{72}$ ✓ «790 Mpc»	*Award MP2 if result is shown with 2sf (instead of math).*	**2**
3.	c		$790\,\text{Mpc} = 2.6 \times 10^9$ light-years ✓ «it takes» 2.6×10^9 years / 2.6 billion years ✓ $= 8.2e16$ sec etc.	*Accept use of 800 Mpc.* *Units must be seen for MP2.* *Award **[1 max]** if answer stated in light-years.*	**2**
3.	d		jets of fast-moving particles ✓ seen in images extending for many light-years ✓ **OR** accretion disk observed ✓ surrounding the black hole «at centre of quasar» ✓ **OR** brightness variability ✓ indicates small size ✓ **OR** orbits of stars/objects near galactic core ✓ imply a large «central» mass ✓	*1 mark for a spectral excess associated with accretion.* *Answers just relating to high luminosity are not sufficient as there are a range of other explanations for this.*	**2**

| 3. | e | | simpler mechanisms (with the known elements) must be ruled out first ✔ | *Give BOD for answers that stress the ubiquity of known/simple elements.* | 1 |
| 3. | f | | $d = 6.5 \times 10^7 \times 9.46 \times 10^{15}$ ✔ $L = 4\pi(6.15 \times 10^{23})^2 \cdot 7.6 \times 10^{-13}$ ✔ $L = 3.61 \times 10^{36}$ «W» ✔ | *Award [3] for bald correct answer.* | 3 |

4.	a		reads peak wavelength correctly ✓ 1.1×10^{-3} «m» ✓ $T = 2.9 \times 10^{-3} / 1.1 \times 10^{-3} =$ «K» ✓	*Allow values within 1.0–1.2 mm.* *To prevent double-loss of marks, only penalise for use of incorrect units when applied, not when reading from the graph* *ECF from MP1.*	**2**
4.	b		expansion of the universe increases wavelength of cosmic background photons ✓ «from Wien's law,» greater peak wavelength implies lower temperature ✓		**2**
4.	c		present-day universe is not homogeneous ✓ «inhomogeneity» seen in large-scale structure ✓ If the original Big Bang / early universe was «perfectly» homogeneous, structure could not have developed / OWTTE ✓	*Accept mentions of superclusters, cluster-sized voids for MP2, but not just "clusters of galaxies".* *A conclusion must be seen.*	**3**
4.	d		Hubble's law ✓ *OR* reference to primordial nucleosynthesis / chemical abundances of old stars ✓ *OR* change of galaxy types/shapes/colours with cosmic distance ✓	*Accept "Cosmological Redshift" or "expansion of the universe"*	**1**

Section B

5.	a	i	straight line seen ✓	*Do not allow lines forced through origin*	**1**
5.	a	ii	$\dfrac{2}{19.5}$ **OR** 0.10 ✓		**1**
5.	b	i	fit line seen **AND** *P* found from two consecutive maxima **OR** average period from two maxima (even if no fit seen) **OR** (3rd – 1st maximum)/2 (even if no fit seen) ✓ 36 days ✓	*Award **[1 max]** if no work seen for MP1.* *Accept answers between 32 and 40 days.*	**2**
5.	b	ii	use of *P* from (b)(i) to read off *L* from Graph 1 ✓ $L = 14\,000\,«L_\square»$ ✓ = 5.4e30W	*Accept values in the range 12 000–16 000.* *If no units, assume solar luminosities.*	**2**
5.	c		$\dfrac{R}{R_\square} = \sqrt{\dfrac{L}{L_\square}}$ ✓ $\dfrac{R}{R_\square} = «\sqrt{14000}» = 120$ ✓ $R = «2\,.\,120\,.\,7 \times 10^5\,\text{km} =» 1.68 \times 10^8\,«\text{km}»$ ✓	*Award **[3]** for bald correct answer.* *ECF from (c)(ii) for luminosity value.* *Accept 1.65×10^8 «km» if no rounding seen.*	**3**
5.	d		$L \alpha P^{\frac{4}{3}}$ ✓ linear fit implies $L \alpha P$ so powers do not match ✓	*Conclusion must be seen for MP2.*	**2**

5.	e		on day 5, temperature is lower than on day 1 ✓ hydrogen lines become weaker ✓ lines from metals / heavy elements become stronger ✓	*Must indicate direction of T change* *No marks for just comments on brightness – temperature/colour needed for mark.*	**2 max**
5.	f	i	 annotates axis with reasonable scale **OR** includes Sun as reference point ✓ draws at least the main sequence and the red giant regions ✓ places Enif within the red giant star (no need to be precise) ✓	*Diagram on left is an example.* *MP1=0 if T scale is shown increasing to the right.* *Shape of MS is not important.* *No need to show Enif data explicitly on diagram.* *Award **[1 max]** if red giant zone is not identified.*	**3**
5.	f	ii	lifetime on the main sequence lasts as long as there is H burning ✓ a star more massive than the Sun has a hotter core ✓ «a hotter core» means than H burns at a faster rate ✓ «thus, Enif spent less time on the MS»		**3**

5.	g		amateurs have more free time to observe ✓ time on professional telescopes is more expensive ✓ amateurs (as a group) can observe the whole sky ✓ professional telescopes are fewer ✓	*Accept other sensible reasons.* *Question could be interpreted as comparing experienced and inexperienced amateurs. Award as appropriate.*	1