Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Astronomy

Standard level

Paper 2

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

Subject Details: Astronomy SL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[40 marks]** and **ONE** question in Section B **[20 marks]**. Maximum total = **[60 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. 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 markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. 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. Indicate this with **ECF** (error carried forward).

10. Significant figures are **only** penalized where noted.

11. **EOR** : Evidence Of Rule: normally associated with a methodology used.

12. **ORA** : Or Reverse Argument.

Section A

1. (a) $\text{constant} = \dfrac{T^2}{R^3} = \dfrac{(365.25\times24\times60\times60)^2}{(1.5\times10^{11})^3} = \dfrac{9.96\times10^{14}}{3.38\times10^{33}} = 2.95\times10^{-19}$

$T = \dfrac{3.16\times10^{7}\text{ s}}{3.15\times10^{7}\text{ s}}$;

$\text{constant} = \dfrac{T^2}{R^3}$ / $\text{constant} = \dfrac{(365.25\times24 \text{ x } 60\times60)^2}{(1.5\times10^{11})^3}$ / $\text{constant} = \dfrac{9.96\times10^{14}}{3.38\times10^{33}}$;

3.0×10^{-19} / 2.95×10^{-19}; **[3]**

(b) $\text{s}^2\,\text{m}^{-3}$; **[1]**

(c) the orbital distance of Jupiter is $7.78\times10^{11}\text{ m}$. As such, Jupiter's orbital period is given by

$T^2 = \text{constant}\times R^3 = 2.95\times10^{-19}\times(7.78\times10^{11})^3 = 1.39\times10^{17}\text{ s}^2$

therefore $T = \sqrt{1.39\times10^{17}} = 3.7\times10^{8}\text{ s}$

$T^2 = 1.39\times10^{17}\ (\text{s}^2)$ / $T = \sqrt{1.39\times10^{17}}$;

$T = 3.7\times10^{8}\text{ s}$; **[2]**

(d) comparing equations (1) and (2) gives

$\text{constant} = \dfrac{4\pi^2}{GM} \Rightarrow M_{Sun} = \dfrac{4\pi^2}{G\times\text{constant}} = \dfrac{4\pi^2}{6.67\times10^{-11}\times2.95\times10^{-19}} = 2.0\times10^{30}\text{ kg}$

$\text{constant} = \dfrac{4\pi^2}{GM}$;

$(M_{Sun} =)\dfrac{4\pi^2}{6.67\times10^{-11}\times2.95\times10^{-19}}$;

$2.0(06)\times10^{30}\text{ kg}$; **[3]**

If 3×10^{-19} is used as the value for the constant, then $M_{Sun} = 1.97\times10^{30}\text{ kg}$ (not 1.99 as given on the formula sheet).

(e) the gravitational force would decrease and so the planet's kinetic energy would be greater than needed and the orbital distance would be expected to increase; **[1]**

2. (a) probes move too slowly;
therefore it would take too much time;
fuel/energy required; **[2]**
Allow the reverse argument ie, we use EM radiation because it has a very high speed therefore takes less time to cover the distances needed.

(b) number of years $= 2007 - 1974 = 33$ years
distance $= 33$ light years
distance = $33 \times 9.46 \times 10^{15} = 3.1(2) \times 10^{17}$ m

33 light years;
$33 \times 9.46 \times 10^{15}$ $33 \times 9.5 \times 10^{15}$;
$3.1(2) \times 10^{17}$ m;
[3]

(c) a natural/whole number which is only divisible by itself and 1; **[1]**

(d) intelligent life would also be aware of prime numbers;
they would look for a pair of prime numbers that produce 1679 in order to make a rectangular image; **[2]**

(e) 2 x 25100 light years = 50200 light years;

$50200 \times 365.25 \times 24 \times 60 \times 60 = 1.6 \times 10^{12}$ s;

[2]

3. (a) (nuclear) bulge;
(galactic) halo; **[2]**

(b) the presence of high mass/OB-type/very bright stars;
triggered by spiral density waves; **[2]**

(c) the disc is where all the gas is;
gas is required to form stars / stars form by the contraction of gas (clouds) / ***OWTTE***; **[2]**
Accept the reverse argument with reference to the Halo/Bulge.

(d) the bright stars (forming the spiral arms) die quickly/are short lived;
new star growth is triggered (to replace the stars that have died quickly)…;
…by spiral density waves/by waves moving through the galaxy;
spiral density waves rotate around/through the disc/galaxy…;
…with a (rotational) speed slightly different to the galaxy; **[2 max]**

(e) red-shift means that the (relative) motion is away from us;
if the galaxy were expanding, all stars would be red-shifted;
stars “behind us and further out” are travelling slower than us (around the galactic centre) / ***ORA***;
our relative motion is away from them; **[2 max]**

4. (a) the age of the universe $= 13.8 \times 10^9$ years

therefore, age of the universe $= 13.8 \times 10^9 \times (365.25 \times 24 \times 60 \times 60) = 4.35(49) \times 10^{17}\,\mathrm{s}$

$4.35(49) \times 10^{17}$; **[1]**

If the student uses 365 days, the answer is $4.35(20) \times 10^{17}$.

(b) using $v = \frac{d}{t} \Rightarrow d = vt = 3.00 \times 10^8 \times 4.35 \times 10^{17} = 1.3(05) \times 10^{26}\,\mathrm{m}$

$d = vt \,/\, d = ct \,/\, d = 3.00 \times 10^8 \times 4.35 \times 10^{17}$;
1.3(1)X10^{26}m;

[2]

Accept ECF from (a) ie, $d = 3.00 \times 10^8 \times (a)$.

(c) $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times (1.31 \times 10^{26})^3 = 9.4 \times 10^{78} \times \mathrm{m}^3$

correct use of the value from (b) into the equation for *V*;
$9.2(03) \times 10^{78}\,\mathrm{m}^3$; **[2]**
Using 1.305×10^{26} *gives* $9.3 \times 10^{78} \times m^3$. *Allow ECF from (b).*

(d) $\mathrm{M}_{\text{universe}} = 3 \times 10^{22} \times 1.99 \times 10^{30} = 5.97 \times 10^{52}\,\mathrm{kg} = 6 \times 10^{52}\,\mathrm{kg}$

6×10^{52}; **[1]**
The answer should be given to 1 significant figure.

(e) $D = \frac{M}{V} = \frac{6 \times 10^{52}}{9.3 \times 10^{78}} = 6 \times 10^{-27}\,\mathrm{kg\,m^{-3}}$

$\frac{6 \times 10^{52}}{9.3 \times 10^{78}}$;
$6 \times 10^{-27}\,\mathrm{kg\,m^{-3}}$; **[2]**
The final answer should be given to 1 significant figure.

(f) $6 \times 10^{-27}\,\mathrm{kg\,m^{-3}}$ is less than the critical density of $1 \times 10^{-26}\,\mathrm{kg\,m^{-3}}$ and so, this would suggest that the universe will expand forever

$6 \times 10^{-27}\,\mathrm{kg\,m^{-3}} < 1 \times 10^{-26}\,\mathrm{kg\,m^{-3}}$;
(this would suggest that) the universe will expand forever; **[2]**
Allow ECF associated with the value from (e) compared with $1 \times 10^{-26}\,kg\,m^{-3}$.

Section B

5. (a) (i)

$$\Delta R = \pm 0.05 R_S = \pm 0.05 \text{x} 6.96 \text{x} 10^8 = \pm 3.48 \text{x} 10^7 m$$

Therefore the fractional uncertainty, $\frac{\Delta R}{R} = \frac{0.05}{1.40} = 0.0357$

[1] Radius of the star is 1.40R_S
Note: Seeing the value 1.4 in the calculation will be enough to give this mark.
[1] Correct method.
[1] Correct answer (0.0357)
Note: Ignore SF.

If the student uses the graph then 0.32(M/M$_S$) is the 8th square from zero and extrapolating up to a straight line drawn through the points gives 1.50 and this gives an answer of the fractional uncertainty of 0.0333.

[3]

(ii) [Any 3 from]

As mass of the star increases, the radius decreases.

The %-uncertainty is the fractional uncertainty x 100 / $\frac{\Delta R}{R}$ x 100

$$100 \ / \ \frac{\Delta R}{R} \text{x} 100$$

ΔR is a constant / is the same for all stars
Therefore as the (stellar) radius decreases, the %-unc increase [ORE].

[3]

(b) correct placing of both error bars; **[1]**
Total error bar length 3 to 5 squares.
Be generous as the error bars are a bit difficult to place.

(c) (i) a straight line can be drawn;
that passes through the error bars; **[2]**
Notice that first point may be implicit, for example, if they have drawn a straight-line of best fit.

(ii) slope = –1.0; *(accept answers in the range – 0.90 to – 1.1 and ignore any units)*
intercept = 1.85; *(accept answers in the range of 1.75 to 1.90)*

correct statement of equation *eg* $\frac{R}{R_s} = 1.85 - 1.0 \times \frac{M}{M_s}$; **[3]**

Accept eg $R = 1.85 - 1.0 \times M$.

(iii) from the X intercept 1.85 M_s; **[1]**
M_s units needed. Accept answers in the range 1.6 M_s to 2.0 M_s, ie constant with a line of best-fit.

(d) the maximum mass corresponds to a star of zero radius/$R = 0$ it is unphysical / radius is zero/too small; **[1]**

(e) (i) smooth curve through data points; **[1]**

(ii) 1.4 M_s / consistent with any line of best-fit even if straight; **[1]**
Do not penalize absence of unit M_s if already penalized earlier.

(iii) answers based on an extrapolation from a curve which is imprecise; **[1]**
The idea is to see a comment about extrapolation outside the data range so plain references to uncertainties in general should not be accepted.

(f) (i) since $\ln R = \ln k + n \ln M$;
a plot of $\ln R$ against $\ln M$ would produce a straight line; **[2]**
Accept log in place of ln.

(ii) with n being the gradient/slope of the graph; **[1]**