M13/4/ASTRO/SP2/ENG/TZ0/XX/M

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

# MARKSCHEME

## May 2013

## ASTRONOMY

## Standard Level

## Paper 2

12 pages

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

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

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

$3.0\times10^{-19}$ / $2.95\times10^{-19}$; ***[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 $3\times10^{-19}$ is used as the value for the constant, then $M_{Sun} = 1.97\times10^{30}$ 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 <u>increase</u>; ***[1]***

**2.** (a) probes move too slowly;
therefore it would take too much time; ***[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 $= 33 \times 9.5 \times 10^{15} = 3.1(35) \times 10^{17}$ m

33 light years;
$33 \times 9.5 \times 10^{15}$;
$3.1(35) \times 10^{17}$ m; ***[3]***

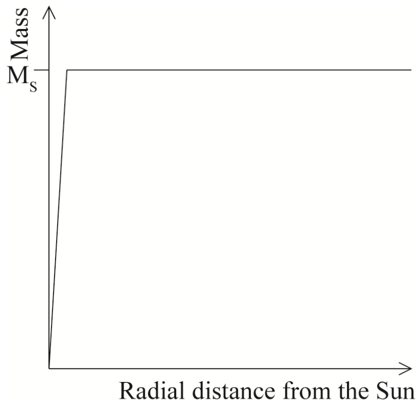
(c) a natural/whole number which is only divisible by itself and 1; ***[1]***

(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) $v = \frac{d}{t} \Rightarrow t = \frac{d}{c} = \frac{3.135 \times 10^{17}}{3 \times 10^{8}} = 1.0 \times 10^{9}$ s

$\frac{3.135 \times 10^{17}}{3 \times 10^{8}}$;
$= 1.0 \times 10^{9}$ s; ***[2]***

**3.** (a)




the sketch is effectively constant for all but very small values of $r$;
the mass-axis has an indication that the height is approximately the mass of the Sun; ***[2]***

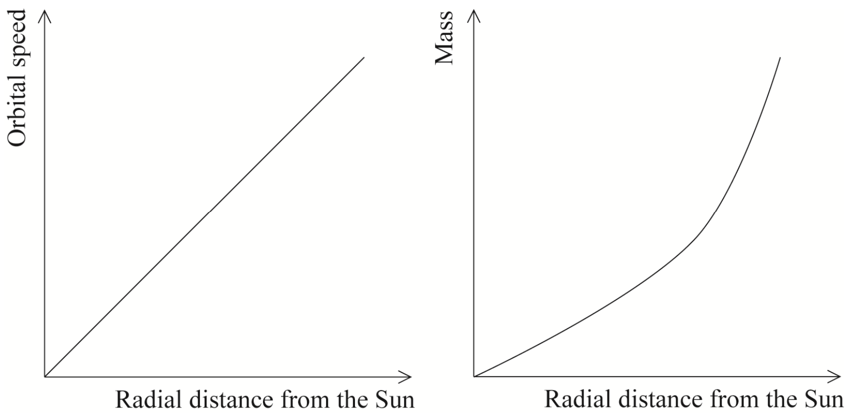
(b) density, $D = \frac{M}{V} \Rightarrow M = D \times V = D \times \frac{4}{3}\pi r^3$ $ie$, $M \propto r^3$

so if the radius increased by a factor of 2, the Mass would increase by a factor of $2^3 = 8$

$2^3$;
8; ***[2]***

(c) the rotation curve is given by

$\frac{GMm}{r^2} = \frac{mv^2}{r}$ leading to $v = \sqrt{\frac{GM}{r}} \propto \sqrt{\frac{r^3}{r}} \propto \sqrt{r^2} \propto r$




rotation curve is linear, starting at $(0, 0)$ and has a positive gradient;
mass-distribution curve is super-linear; ***[2]***

(d) the distance to the outer stars in the galaxy; ***[1]***

(e) from the motion of gas clouds/globular clusters; ***[1]***

(f) the mass is thinning out / the mass is becoming less dense;
significant amounts of mass are still present / we have not reached the edge of the mass; ***[2]***

**4.** (a) mass of the Milky Way $= 1.3\times10^{12}\times1.99\times10^{30} = 2.587\times10^{42}$ kg
mass of the Andromeda $= 7.1\times10^{11}\times1.99\times10^{30} = 1.413\times10^{42}$ kg

$M_{MW}\left(=2.587\times10^{42}\text{ kg}\right) = 2.6\times10^{42}$ kg ;
$M_{A}\left(=1.413\times10^{42}\text{ kg}\right) = 1.4\times10^{42}$ kg ; ***[2]***
*Award **[1 max]** if either answer is written to anything other than 2 significant figures.*

(b) number of protons in Milky Way $= \dfrac{2.587\times10^{42}}{1.67\times10^{-27}} = 1.55\times10^{69}$
number of protons in Andromeda $= \dfrac{1.413\times10^{42}}{1.67\times10^{-27}} = 8.46\times10^{68}$

number of protons in Milky Way $= 1.55\times10^{69}$ protons;
number of protons in Andromeda $= 8.46\times10^{68}$ protons; ***[2]***

(c) distance $= 2.5\times10^{6}\times9.47\times10^{15} = 2.368\times10^{22}$ m

$2.368\times10^{22}$ m ; ***[1]***

(d) the gravitational force is given by
$$F_G = G\frac{M_1 M_2}{d^2} = 6.67\times10^{-11}\,\frac{2.59\times10^{42}\times1.41\times10^{42}}{\left(2.37\times10^{22}\right)^2} = 4.336\times10^{29}\text{ N}$$

$4.3\times10^{29}$ (N); ***[1]***
*The answer must be given to at least 2 significant figures.*

(e) $Q_{\text{e-p}} = 1.60\times10^{-19}\times0.01 = 1.60\times10^{-21}$ C

$1.60\times10^{-21}$ C; ***[1]***

(f) the electric force ($F_E$) is given by
$$F_E = 9.0\times10^{9}\times\frac{Q_1 Q_2}{d^2} = 9.0\times10^{9}\times\frac{2.47\times10^{48}\times1.35\times10^{48}}{(2.4\times10^{22})^2} = 5.2\times10^{61}\text{ N}$$

$9.0\times10^{9}\times\dfrac{2.47\times10^{48}\times1.35\times10^{48}}{(2.4\times10^{22})^2}$;
$5.2\times10^{61}$ N ; ***[2]***
*The value for $F_E$ will be between 5.2 and 5.4 depending on the value used from (c).*
*Allow ECF from (c) ie,* $F_E = 9.0\times10^{9}\times\dfrac{2.47\times10^{48}\times1.35\times10^{48}}{(\text{part c})^2}$.

(g) the attractive force of gravity is much smaller than the repulsive electric force so the motion of the galaxies suggests that gravity only is acting

only gravity / not electric; ***[1]***

*This last part is not testing that the candidate knows that gravity is the force acting on the galaxies – this information is given in the question. It is getting the candidate to realise that electric forces are likely to NOT be acting because if they were, they are so strong by comparison, that galaxies would repel.*

**SECTION B**

**The Brighest Supernova Ever**

**5.** (a) $150M_{\odot}$; ***[1]***

(b) the outer material of the photosphere is weakly held by gravity;
and the force due to the solar wind is larger; ***[2]***

(c) radiation pressure; ***[1]***

(d) advantage / disadvantage

easy to use;
easy to access;
easy to modify;
easy to change;
no distortion/absorption of EM radiation due to the atmosphere;
there are significant cost differences; ***[2 max]***
*Any answer could be given as an advantage or disadvantage depending on how it is given. Do not allow answers which are the opposite of each other.*

(e) lifetime would be small;
because the core will be hotter than a smaller star;
and it burns its fuel faster; ***[3]***

(f) such large stars are rare/less abundant; ***[1]***

(g) distance to SN 2006gy $= 240\times10^{6}$ ly ;
distance to Eta Carinae $= 7500$ ly ; ***[2]***

(h) the luminosity rises/increases;
because the size increases; ***[2]***

(i) the brightness ($b$) and distance ($d$) are related via $b=\frac{L}{4\pi d^{2}}$, and so

$$b_1d_1^2=b_2d_2^2\Rightarrow\frac{b_2}{b_1}=\left(\frac{d_1}{d_2}\right)^2=\left(\frac{240\times10^6}{7500}\right)^2=1.0\times10^9$$

$$b=\frac{L}{4\pi d^2};$$

$$\frac{b_2}{b_1}=\left(\frac{d_1}{d_2}\right)^2\ /\ \frac{b_2}{b_1}=\left(\frac{240\times10^6}{7500}\right)^2\ /\ \frac{b_2}{b_1}=\left(3.2\times10^4\right)^2;$$

$1.0\times10^{9}$; ***[3]***

(j) giant stars make elements greater than Fe (in the periodic table);
the supernova throws these elements into the universe; ***[2]***

(k) black holes retain the heavy elements needed for our kind of life; ***[1]***

**Alien Matter in the Solar System: A Galactic Mismatch**

**6.** (a) seeding requires less time / there is not enough time to allow molecules to randomly form / *OWTTE*; ***[1]***

(b) (i) protons;
electrons;
they both have charge; ***[3]***

(ii) the escape velocity is given by

$$v_{escape} = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2\times6.67\times10^{-11}\times1.99\times10^{30}}{6.96\times10^{8}}} = \sqrt{3.8\times10^{11}} = 6.2\times10^{5}\text{m s}$$

$v_{escape} = \sqrt{\frac{2\times6.67\times10^{-11}\times1.99\times10^{30}}{6.96\times10^{8}}}$ / $v_{escape} = \sqrt{3.8\times10^{11}}$;
$6.2\times10^{5}\text{m s}$; ***[2]***

(iii) they have a very low mass and so are not significantly affected by the gravitational effects of the planets; ***[1]***

most of the space they are travelling through is empty space;
the space between the planets is huge;
the planets occupy a tiny fraction of the solar system space; ***[1 max]***

(c) (i) the frequency $(f)$ of the IBEX orbit is 0.11 orbits per day. Hence the period $(T)$ is given by

$$T = \frac{1}{f} = \frac{1}{0.11} = 9.09 \text{ days} = 7.9\times10^{5}\text{ s}$$

$T = \frac{1}{f}$ / $T = \frac{1}{0.11}$;
$7.9\times10^{5}\text{ s}$; ***[2]***
*The answer must be given to at least 2 significant figures.*

(ii) in two years, with a period of $7.9\times10^{5}\text{ s}$, this produces a number of orbits equal to

$$\text{number of orbits} = \frac{2\times365.25\times24\times3600}{7.9\times10^{5}} = 79.9 \text{ orbits}$$

79.9 / 79.8 / 78.9 / 78.8; ***[1]***
*Allow ECF for days in a year (365) and for the use of* $8\times10^{5}$ *s*.

(d) it is inert / it does not react (easily/readily) with other elements/atoms; ***[1]***
*Do not accept it is a noble gas / it is relatively abundant.*

(e) *The first mark is for why a measurement for neon on its own is not useful. For example*
the amount on its own is meaningless;
the amount tells us nothing;
the amount might be due to some form of general spreading out of the atoms as they travel into the solar system; ***[1 max]***

*The second mark is for why the comparison is useful. For example*
all factors affecting the general motion of the atoms and how they spread out or get trapped/blocked by planets would be expected to affect all the atoms in the same way; ***[1]***

(f) (i) $$\text{percentage Ne} = \frac{\text{amount of neon}}{\text{total amount of atoms}}$$

$$\%\ Ne\ in\ galactic\ wind = \left(\frac{20}{94} = \right) 0.21\ /\ 21\%\,;$$

$$\%\ Ne\ in\ solar\ system = \left(\frac{20}{131} = \right) 0.15\ /\ 15\%\,;$$ ***[2]***

(ii) the greater relative amount of oxygen is in <u>the solar system</u>; ***[1]***

(g) the solar system evolved in a separate, more oxygen-rich part of the galaxy;
a great deal of oxygen lies trapped in interstellar dust grains or ices; ***[1 max]***

(h) *Time:* a large amount of time on the planet, without the Sun dying / an orbit around a Sun which has a main sequence lifetime of at least 5 billion years;
*Liquid water:* the development of life requires chemical evolution and this requires chemicals to come together, collide and possibly react;
*Temperature:* if the temperature is too low then there will not be enough energy to allow chemical reactions to occur, and if the temperature is to high, then proteins denature;
*Magnetic Field:* cosmic radiation from the Sun is channelled around the Earth by its magnetic field;
*Atmospheric density:* the density of the atmosphere needs to be high enough to allow a reasonable albedo to ensure that not all the solar radiation reaches the planet's surface; ***[2 max]***