Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2016

Astronomy

Standard level

Paper 2

11 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) $\lambda_{\text{max}} = \frac{2.90\times10^{-3}}{T} = \frac{2.90\times10^{-3}}{(2300+273)} = 1.13\times10^{-6}\,\text{m}$

use of Wien's displacement law;
$T = 2300+273$ / $2573\ (\text{K})$;
$1.13\times10^{-6}\,\text{m}$; **[3]**

Award **[2]** *for:* $\lambda_{max} = 1.26\times10^{-6}\ m$

(b) (comparing this value to Figure 1, this is in the) infrared; **[1]**

(c) no;
the shape of the black body curve depends only on the source temperature; **[2]**

(d) black-body radiation requires the source to be opaque / the emitting medium is transparent;
black body source needs there to be a strong interaction between the radiation and the emitting medium; **[2]**

(e) line spectrum / a spectrum that consists of a set of discrete lines; **[1]**

(f) because the emitted spectral lines are characteristic of the particular atom/neon / *OWTTE*; **[1]**

2. (a) rocky;

Any ***one*** *for* **[1]** *from:*
nebula would be denser closer to the Sun;
collisions within the nebular are more frequent closer to the sun;
volatile gases are lost quickly when the planet is closer to the Sun; **[2 max]**

(b) $M = \rho.\frac{4}{3}\pi r^3 = 5000 \times \frac{4}{3}\pi \times (1800000)^3 = 1.2 \times 10^{23}$ kg

correct use of $M = \rho.\frac{4}{3}\pi r^3$;
1.2 □10^{23} kg; **[2]**

(c) $v_{esc} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 1.2 \times 10^{23}}{1800000}} = 2.98 \times 10^3 \text{ m s}^{-1} = 2.98 \text{ km s}^{-1}$

correct use of $v_{esc} = \sqrt{\frac{2GM}{R}}$;
2980 km s^{-1}; **[2]**

(d) $\frac{2.98}{11} = 0.27$ times the escape velocity of the Earth; **[1]**

(e) less dense because the lower escape velocity means it is easier for the gas to escape from the planet; **[1]**

(f) T-Tauri phase of the Sun;
very high period of solar wind; **[2]**

3. (a) $b = \dfrac{L}{4\pi d^2} \;\Rightarrow\; d = \sqrt{\dfrac{L}{4\pi b}} = \sqrt{\dfrac{5.5 \times 10^{9} \times 3.82 \times 10^{26}}{4\pi \times 1.4 \times 10^{-13}}} = \sqrt{1.194 \times 10^{48}} = 1.09 \times 10^{24}\text{ m}$

correct use of $b = \dfrac{L}{4\pi d^2}$;

conversion of luminosity into Watts;
1.09×10^{24} m / 1.1×10^{24} m;

Answer is 5.6×10^{10} if luminosity is left as 5.5×10^{9}.
Full marks are given for simply scaling by $\left(\dfrac{1}{0.85}\right)^{0.5}$. **[3]**

(b) $b = \dfrac{L}{4\pi d^2} \;\Rightarrow\; d = \sqrt{\dfrac{L}{4\pi b}} = \sqrt{\dfrac{5.5 \times 10^{9} \times 3.82 \times 10^{26}}{4\pi \times 1.4 \times 10^{-13} \times 0.85}} = 1.18 \times 10^{24}\text{ m}$

brightness, b = $0.85 \times 1.40 \times 10^{-13}$ / 1.19×10^{-13};
1.18×10^{24} m; **[2]**

(c) scattering of the light;
absorption (and re-emission) of the light; **[2]**

(d) light intensity becomes too small; **[1]**

(e) Hubble's law;
measurement of the red-shift of the overall light from a galaxy; **[2]**

4. (a) blue-shift;
Andromeda is moving towards the Milky Way/Sun/Earth/us; **[2]**

(b) $z = \frac{H_0}{c} d = \frac{72 \times 10^3 / 10^6 \times 3.1 \times 10^{16}}{3 \times 10^8} \times 2.40 \times 10^{22} = 0.000186$

correct use of Hubble's law;
0.000186; **[2]**

(c) $z_{motion} = z_{measured} - z_{cosmological} = -0.001001 □ 0.000186 = -0.001186$

$z = \frac{v}{c} \Rightarrow v = zc = -0.001186 \times 3 \times 10^8 = -356 \text{ km / s}^{-1}$

Andromeda's red-shift:
$z = -0.001186$;

Actual speed:
$(-)356 \text{ km s}^{-1}$;
Accept the answer in $m s^{-1}$. **[2]**

(d) no;
relativity places no restriction on the relative speed of an object travelling due to the expansion of space time / only places a restriction on the speed of an object moving *through* spacetime; **[2]**

(e) $t = \frac{d}{v} = \frac{2.40 \times 10^{22}}{300.3 \times 10^3} = 7.99 \times 10^{16} \text{s} = 2.5 \text{ billion years}$

7.99×10^{16} s;
2.5 billion years; **[2]**

Section B

"Bright spot" on Ceres has dimmer companion

5. (a) *Similarity*:
Any one for [1] *from:*
in a stable orbit around the Sun;
massive enough to hold its shape due to its own gravity;
a body orbiting the Sun that does not give out its own visible light;

Difference:
Planets have cleared the volume around their orbit of large objects / *OWTTE*; **[2 max]**

(b) Pluto / Makemake / Haumea / Eris; **[1]**

(c) Jupiter's gravitational influence is very strong / has a significant effect on the asteroid belt;
collisions within the asteroid belt/between asteroids are affected by Jupiter's gravitational influence;
Jupiter's gravitational effect increases the KE of those objects moving towards it;
Jupiter's gravitational effect decreases the KE of those objects moving away from it;
kinetic energy difference in a collision is greater than expected, due to Jupiter's influence;
objects in the asteroid belt cannot accrete / move apart after the collision / *OWTTE*; **[3 max]**

(d) $$\text{Mass of Ceres} = \frac{\text{mass of Earth}}{6370} = \frac{5.98 \times 10^{24}}{6370} = 9.39 \times 10^{20}\ \text{kg}$$

9.<u>39</u> × 10^{20} kg**;** **[1]**

(e)
$$g_{\text{Ceres}} = \frac{GM_{Ceres}}{R^2} = \frac{6.67 \times 10^{-11} \times 9.39 \times 10^{20}}{\left(\frac{950}{2} \times 10^3\right)^2} = 0.278\,\text{N}\,\text{kg}^{-1}$$

correct use of $g_{\text{Ceres}} = \frac{GM_{Ceres}}{R^2}$;

0.278 N kg^{-1}**;** **[2]**

(f)

$$D_{Ceres} = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi R^3} = \frac{9.39\times10^{20}}{\frac{4}{3}\pi\left(\frac{950}{2}\times10^3\right)^3} = \frac{9.39\times10^{20}}{4.49\times10^{17}} = 2090\,\text{kg}\,\text{m}^{-3}$$

Volume:
4.49×10^{17} m^3;

Density:
correct use of $D = \frac{M}{V}$;
D_{Ceres} = 2090 / 2100 / 2092**;** **[3]**

(g) material from the inside of the object is heated / mobile**;**
(material) is released from the inside of the object**;**
cover the surface of the object**;**
(material) is lighter in colour than the surface material**;**
(hence its) albedo would be greater / it would look brighter**;** **[2 max]**

(h) collision breaks through the surface of Ceres / the outer layer is removed**;**
inner material is heated**;**
(heated) due to the conversion of the KE of the impactor**;**
inner material is thrown out from Ceres**;**
inner material is now visible / inner material is brighter**;** **[2 max]**

(i) with reference to (e), a low value for *g* means that ejected material is more likely to escape from Ceres / leave the lower surface exposed**;**

with reference to (f), the low density (of 2100 kg m^{-3}) suggests that Ceres has a large proportion of ice which would be highly reflective / *OWTTE***;** **[2]**

(j) important information on how the solar system formed;
gives information on the composition of the solar system; **[2]**

Accept any sensible comment about the importance of investigating objects in the solar system.

NASA's Chandra detects record-breaking outburst from Milky Way's black hole

6. (a) direction to the centre of the galaxy is in the constellation of Sagittarius; **[1]**

(b) centre of the galaxy is in the disk;
direction has gas in the way;
gas absorbs and redirects any radiation / photoextinction occurs;
answers relating to the event horizon of the black hole; **[2 max]**

(c) supermassive black hole at the centre;
(the central BH is) surrounded by (gas) clouds / gas clouds are in orbit around the BH; **[2]**

(d) light cannot be emitted from a black hole; **[1]**

(e) *Either:*

any ***three*** *for* **[3]** *from*:
asteroid debris would be falling/spiralling into the SMBH;
gravitational field strength around the BH is very large;
particles lose GPE;
GPE turns into KE;
friction/interactions within the material to heat it up/raise the temperature;
as temperature rises, the energy of the output rises into the X-ray spectrum;

OR

any ***three*** *for* **[3]** *from*:
magnetic field lines exist within the surrounding gas**;**
differential rotation cause the magnetic flux to become concentrated**;**
flux reconfigures itself;
release of energy accelerates charged particles**;**
X-rays are emitted when such accelerated particles collide with other particles in the gas**;** **[3 max]**

(f) $m_B - m_A = -2.5\log\left[\frac{b_B}{b_A}\right] = -2.5\log[400] = -6.5$

brightness ratio = 400 (from the article);
correct use of $m_B - m_A = -2.5\log\left[\frac{b_B}{b_A}\right]$;
–6.5; **[3]**

Award ***[2 max]*** *for (+)6.5.*

(g) $M_{BH} = 4.5\times10^6 \times \text{mass of the Sun} = 4.5\times10^6 \times 1.99\times10^{30} = 8.96\times10^{36}\text{ kg}$

8.96×10^{36} (kg); **[1]**

(h) $v_{esc} = c = \sqrt{\frac{2GM}{R}} \Rightarrow c^2 = \frac{2GM}{R} \Rightarrow R = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 8.96 \times 10^{36}}{\left(3 \times 10^8\right)^2} = 1.32 \times 10^{10}$ m

$v_{esc} = c$;

correct use of $v_{esc} = \sqrt{\frac{2GM}{R}}$;

1.32×10^{10} m; **[3]**

(i) $L = \text{flare distance} - \text{distance of event horizon} = \frac{2.4 \times 10^{13}}{100} - 1.32 \times 10^{10} = 2.27 \times 10^{11}$ m

$\text{Distance in AU} = \frac{2.27 \times 10^{11}}{1.5 \times 10^{11}} = 1.51\text{AU}$

flare distance $= 2.4 \times 10^{11}$ m;
distance between flare and event horizon $= 2.27 \times 10^{11}$ m;
distance in AU $= 1.5$; **[3]**

(j) intensity is too weak; **[1]**