

Formulae and Data Sheet

Formulae

Equation of Time = Apparent Solar Time (AST) – Mean Solar Time (MST)	
Kepler's 3rd law:	$\frac{T^2}{r^3} = \text{a constant}$
Magnification of telescope:	magnification = $\frac{f_o}{f_e}$
Distance modulus formula:	$M = m + 5 - 5 \log d$
Redshift formula:	$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c}$
Hubble's law:	$v = H_0 d$

Data

Mass of Earth	6.0×10^{24} kg
Mean diameter of Earth	13 000 km
Mean diameter of Moon	3500 km
Mean diameter of Sun	1.4×10^6 km
One Astronomical Unit (AU)	1.5×10^8 km
Mean Earth to Moon distance	380 000 km
One light year (l.y.)	9.5×10^{12} km
One parsec (pc)	3.1×10^{13} km = 3.26 l.y.
Sidereal day of Earth	23 h 56 min
Synodic day of Earth	24 h 00 min
Temperature of solar photosphere	5800 K
Hubble Constant	68 km/s/Mpc
Speed of light in vacuum	3.0×10^8 m/s

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Name	Type of body	Mean distance from Sun/AU	Sidereal period/ Earth year	Mean temperature /°C	Diameter /1000 km	Mass/ Earth mass	Ring systems	Moons
Mercury	planet	0.38	0.24	170	4.9	0.055	no	none
Venus	planet	0.72	0.62	470	12.1	0.82	no	none
Earth	planet	1.0	1.0	15	12.8	1.00	no	1: the Moon
Mars	planet	1.5	1.9	-50	6.9	0.11	no	2 small moons: Deimos and Phobos
Ceres	dwarf planet	2.8	4.6	-105	0.95	1.5×10^{-4}	no	none
Jupiter	planet	5.2	11.9	-150	143	318	yes	4 major moons: Ganymede, Callisto, Europa, Io >60 others
Saturn	planet	9.5	29.5	-180	121	95	yes	5 major moons: including Titan, Iapetus >55 others
Uranus	planet	19.1	84.0	-210	51	15	yes	5 major moons: including Titania, Oberon >20 others
Neptune	planet	30.0	165	-220	50	17	yes	1 major: Triton >12 others
Pluto	dwarf planet	39.5	248	-230	2.4	2.2×10^{-3}	no	1 major: Charon >4 other moons
Haumea	dwarf planet	43.1	283	-241	1.4	6.7×10^{-4}	no	2
Eris	dwarf planet	67.8	557	-230	2.3	2.8×10^{-3}	no	at least 1



Answer ALL questions. Write your answers in the spaces provided.

Some questions must be answered with a cross . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

- 1 (a) A student used a telescope to make sketches of some planets.

The student wrote a description of each planet.

Identify each planet from its description and sketch.

- (i) A small, bright disc with a clearly visible ring system, as shown in Figure 1.

(1)



Figure 1

- A Jupiter
- B Mars
- C Neptune
- D Saturn

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(ii) A small, bright disc with faint surface features including bands and a large spot, as shown in Figure 2.

(1)



Figure 2

- A** Jupiter
- B** Mars
- C** Neptune
- D** Saturn

(iii) A small, red disc with a white polar cap, as shown in Figure 3.

(1)

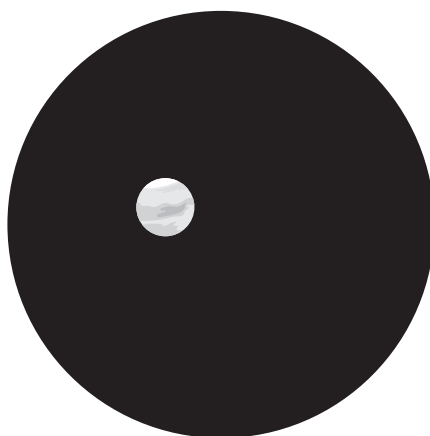


Figure 3

- A** Jupiter
- B** Mars
- C** Neptune
- D** Saturn

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(b) A student photographs some astronomical objects through a telescope.

The student writes a description of each object.

Identify each object from its description and image.

(i) A fuzzy cloud in the shape of a ring, as shown in Figure 4.

(1)

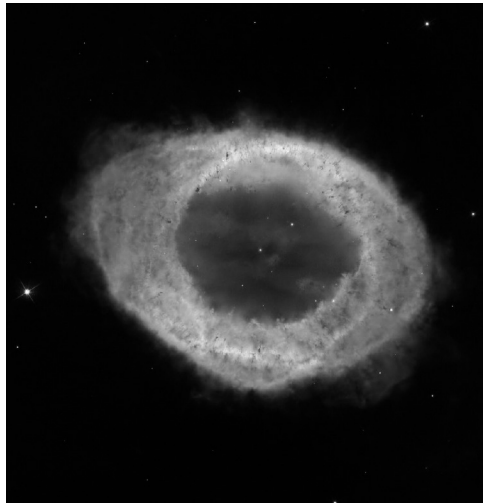


Figure 4

- A** globular cluster
- B** open cluster
- C** planetary nebula
- D** protostar



(ii) A ball-shaped cloud of thousands of stars, as shown in Figure 5.

(1)

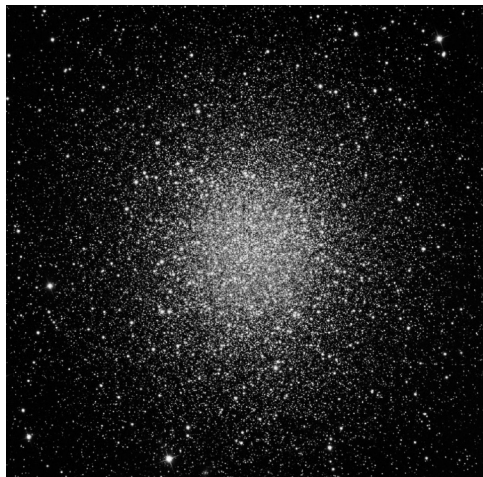


Figure 5

- A emission nebula
- B globular cluster
- C open cluster
- D planetary nebula

(iii) A fuzzy cloud with an irregular shape, as shown in Figure 6.

(1)



Figure 6

- A emission nebula
- B globular cluster
- C open cluster
- D protostar

(Total for Question 1 = 6 marks)

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- 2 (a) Which of the following do astronomers think is the origin of the Earth's water? (1)
- A comets
 - B the solar wind
 - C the Moon
 - D the Van Allen belts

- (b) Which of the following has been investigated using 21cm radio waves? (1)
- A interior of the Moon
 - B location of black holes
 - C origin of meteorites
 - D structure of our galaxy

- (c) State the name of a type of active galaxy. (1)

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- (d) (i) An object needs to travel at a certain velocity in order to leave the Moon's gravity. (1)
- State the name of this velocity.



(ii) Figure 7 shows two images of the Moon.

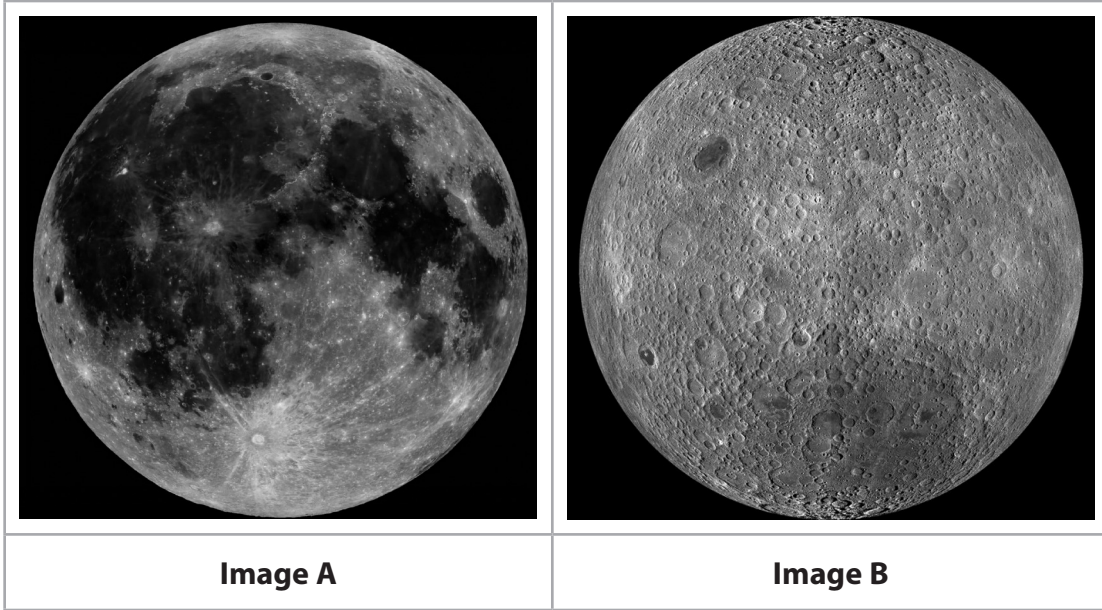


Figure 7

Explain why **Image B** in Figure 7 must have been taken from a spacecraft.

(2)

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(Total for Question 2 = 6 marks)

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3 (a) The Milky Way galaxy belongs to a collection of galaxies.
State the name of this collection of galaxies. (1)

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(b) Astronomers observing galaxies have concluded that the Universe is expanding.
Describe these observations.
You may include a clearly labelled diagram in your answer. (2)

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(c) State how the value of the Hubble Constant can be used to estimate the age of
the Universe. (1)

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(d) Figure 8 shows an image taken by the Wilkinson Microwave Anisotropy Probe (WMAP).

The image shows the differences in temperature within the cosmic microwave background (CMB) radiation.

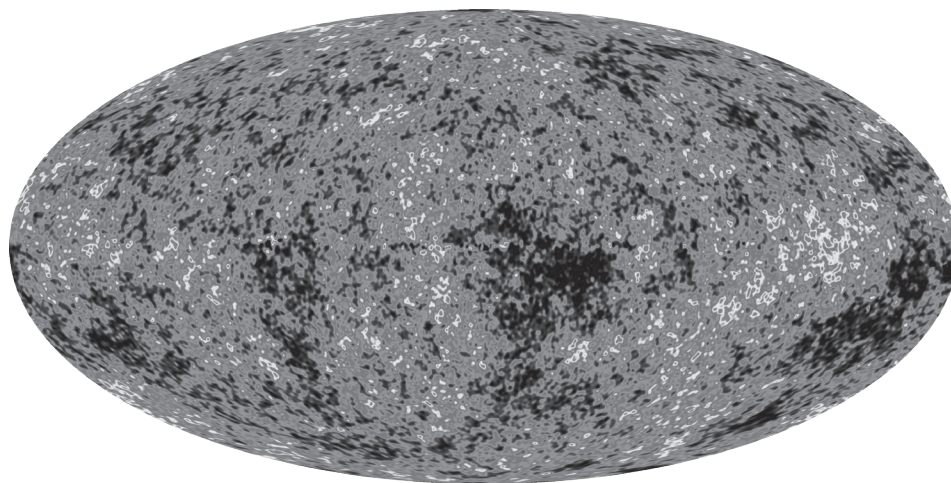


Figure 8

Explain how the data in Figure 8 have helped to explain the current structure of the Universe.

(2)

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(Total for Question 3 = 6 marks)



4 (a) Mercury, Venus, Earth and Mars are called terrestrial planets.

Table 1 lists some features of planets.

Feature	Type of planet
Solid rocky surface	T
Mean surface temperature below $-100\text{ }^{\circ}\text{C}$	
Ring system	
Few or no moons	
Low density (similar density to water)	G
Diameter less than 20 000 km	

Table 1

Complete Table 1 by writing either the letter **T** or the letter **G** next to each feature.

Use the letter **T** for a terrestrial planet feature.

Use the letter **G** for a gas giant planet feature.

Two rows have been completed for you.

Use information from the Formulae and Data Sheet.

(2)



(b) Figure 9 shows the orbital paths of Jupiter and Neptune around the Sun.
 The paths of four other objects are also shown, labelled A, B, C and D.

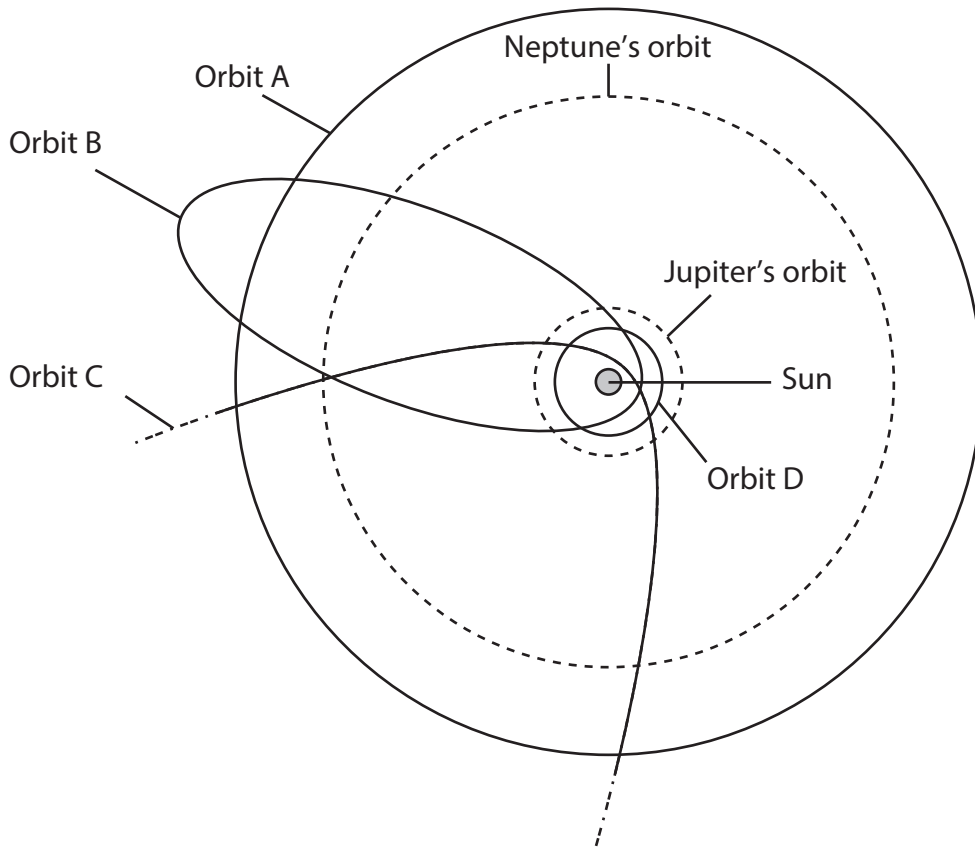


Figure 9

(i) Identify the orbit in Figure 9 (A, B, C or D) that shows the path of a typical short-period comet. (1)

Orbit:

(ii) Identify the orbit in Figure 9 (A, B, C or D) that shows the path of a typical dwarf planet located within the asteroid belt. (1)

Orbit:

(iii) Identify the orbit in Figure 9 (A, B, C or D) that shows the path of a typical Kuiper Belt Object (KBO). (1)

Orbit:

(iv) Identify the orbit in Figure 9 (A, B, C or D) that shows the path of a typical long-period comet. (1)

Orbit:



(c) State the name of each of the following areas of the Solar System, using these descriptions.

- (i) The doughnut-shaped region around the Earth where charged particles have been trapped in the Earth's magnetic field.

(1)

- (ii) The region where long-period comets are thought to originate.

(1)

- (iii) The region where the solar wind has a greater influence than the interstellar medium.

(1)

(Total for Question 4 = 9 marks)



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5 (a) The Bayer system can be used to name the brightest stars in a constellation.

One part of the Bayer system is a Greek letter.

State the other part of the Bayer system.

(1)

(b) Table 2 shows the mass, absolute magnitude and lifetime of four stars.

Star	Mass (compared to the Sun)	Absolute magnitude, M	Lifetime (years)
A	0.1	10	10^{11}
B	1	5	10^{10}
C	10	0	10^9
D	100	-5	10^8

Table 2

(i) Identify the star in Table 2 (A, B, C or D) that is most like the Sun.

(1)

Star:

(ii) Stars with a greater mass have a shorter lifetime.

Explain this relationship.

You may use information from Table 2.

(3)



(iii) Star C is located 1000 pc from Earth.

Calculate the apparent magnitude of star C.

Use the equation:

$$M = m + 5 - 5 \log d \quad (2)$$

Apparent magnitude of star C =

(c) The observed brightness of a star decreases in proportion to the square of its distance from Earth.

The Sun has an apparent magnitude of -27 when viewed from a distance equal to the radius of the Earth's orbit.

Calculate the apparent magnitude of the Sun when viewed from a distance of 10 AU.

(2)

Apparent magnitude of the Sun =

(Total for Question 5 = 9 marks)

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P 7 8 6 9 2 A 0 1 7 4 0

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6 (a) Pinhole projection is one safe method for observing the Sun.

Describe **one other** safe method for observing the Sun.

You may include a clearly labelled diagram in your answer.

(2)

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(b) State the name of the internal division of the Sun where the proton-proton cycle occurs.

(1)

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(c) Table 3 shows the Sun's temperature at different distances from its centre.

Distance from centre of Sun (Sun's radius)	Sun's temperature (K)
0.0	2×10^7
0.1	1×10^7
0.2	6×10^6
0.4	3×10^6
0.6	3×10^6
0.8	1×10^6
1.0	6×10^3

Table 3

Some of the data in Table 3 are shown as a graph in Figure 10.



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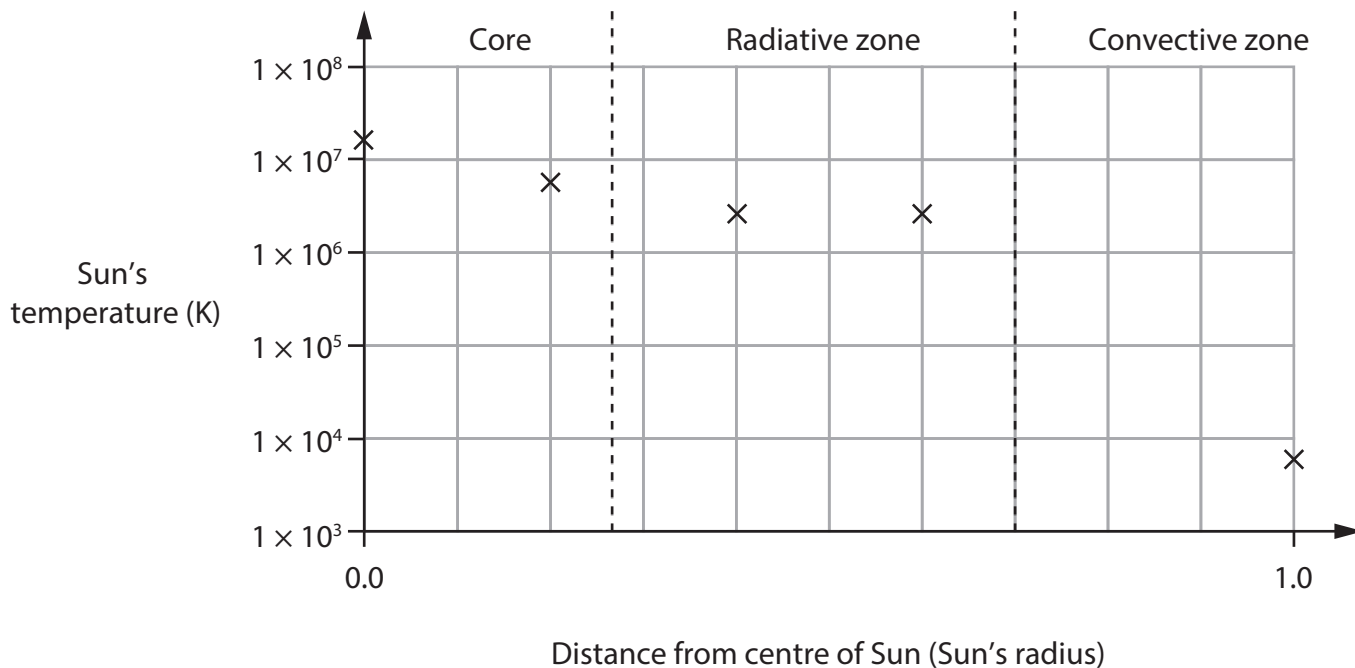


Figure 10

(i) Complete the graph in Figure 10 to show all the data in Table 3.

You should:

- complete the scale on the horizontal (distance) axis
- plot the remaining points
- draw a line of best fit.

(3)

(ii) Estimate the average temperature of the Sun's radiative zone.

(1)

Average temperature = K

(iii) Identify the internal division of the Sun that has the greatest range of temperatures.

(1)



P 7 8 6 9 2 A 0 2 1 4 0

(iv) Figure 11 shows a graph of the relative density of the Sun at different distances from its centre.

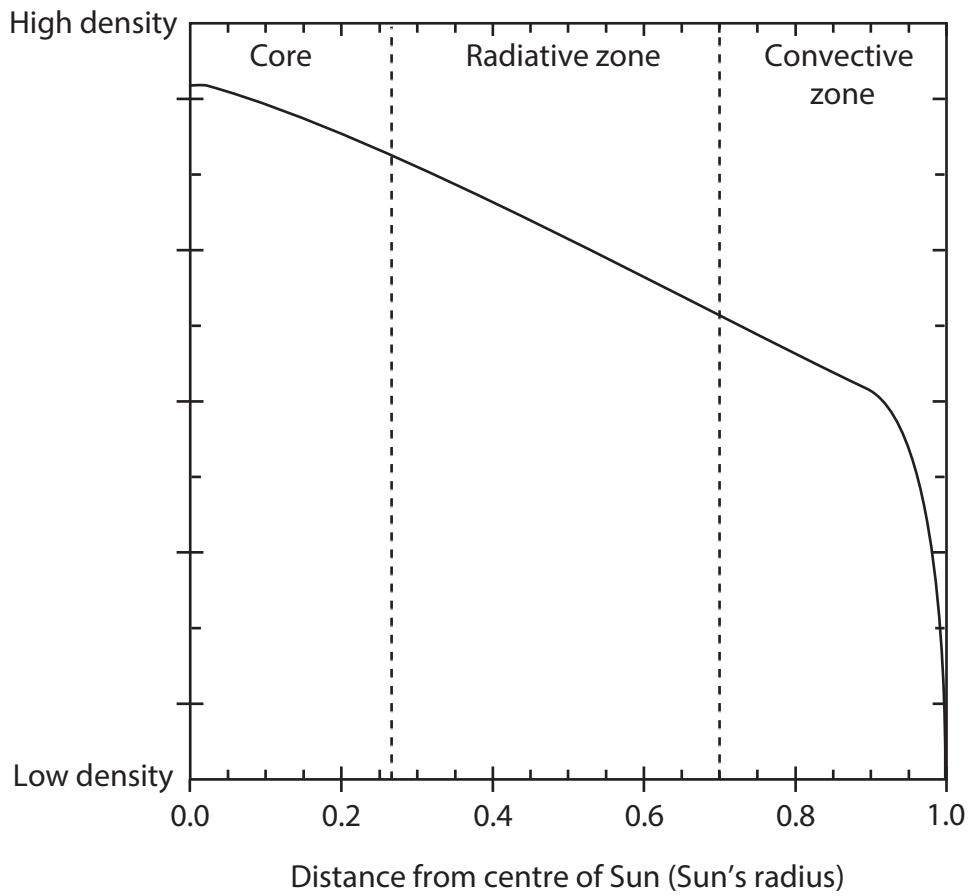


Figure 11

Analyse Figure 10 and Figure 11 in order to determine if there is a relationship between the Sun's temperature and its relative density.

(3)

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(Total for Question 6 = 11 marks)



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QUESTION 7 BEGINS ON THE NEXT PAGE



7 (a) Mira is a star in the constellation Cetus.

Mira is an example of a long-period variable star.

(i) Which of the following could be the period of an observed long-period variable star such as Mira?

(1)

- A 3.3 days
- B 3.3 weeks
- C 330 days
- D 330 years

(ii) Mira is a red giant star in the late stages of stellar evolution.

Mira has a mass of 1.2 solar masses.

Describe how Mira will evolve in the future.

(2)

.....

.....

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(iii) The brightness of Mira changes because of a change in its surface temperature.

At lower temperatures, some of Mira's visible light becomes infrared.

Explain how a drop in Mira's surface temperature affects its brightness.

(2)

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(iv) Figure 12 shows an ultraviolet image of Mira. A tail can be seen.

The tail is caused by the star moving through space.

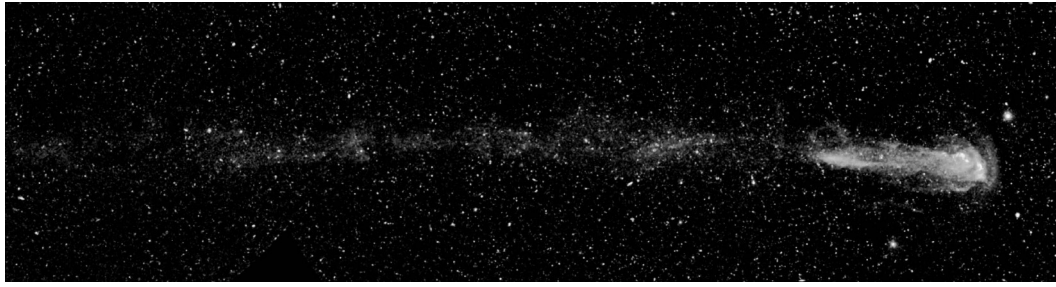


Figure 12

Mira has a velocity of 130 km/s and has been creating this tail for 30 000 years.

Calculate the length of the tail.

Use information from the Formulae and Data Sheet and the equation:

$$\text{Length of tail} = \text{speed} \times \text{time}$$

Give your answer in parsecs.

(3)

Length of tail = parsecs

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(b) Table 4 shows light curves for three variable stars.

Variable star	Light curve
<p style="text-align: center;">A</p>	<p style="text-align: center;">Apparent magnitude</p> <p style="text-align: center;">Time (days)</p>
<p style="text-align: center;">B</p>	<p style="text-align: center;">Apparent magnitude</p> <p style="text-align: center;">Time (days)</p>
<p style="text-align: center;">C</p>	<p style="text-align: center;">Apparent magnitude</p> <p style="text-align: center;">Time (days)</p>

Table 4

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Evaluate the data in Table 4 in order to identify which of the stars is:

- a supernova
- a Cepheid variable
- an eclipsing binary.

Justify your answer in each case.

(6)

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(Total for Question 7 = 14 marks)



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- 8 (a) Table 5 shows a comparison between the Hubble Space Telescope (HST) and the James Webb Space Telescope (JWST).

	Hubble Space Telescope (HST)	James Webb Space Telescope (JWST)
Objective diameter (m)	2.4	6.5

Table 5

- (i) Calculate how many times greater the resolution of the JWST is compared to the resolution of the HST.

Use the information in Table 5.

(1)

..... times greater

- (ii) Calculate how many times greater the light grasp of the JWST is compared to the light grasp of the HST.

Use the information in Table 5.

(1)

..... times greater

- (iii) The JWST objective is made up from 18 smaller mirrors, instead of one large mirror.

Give **two** reasons for this.

(2)

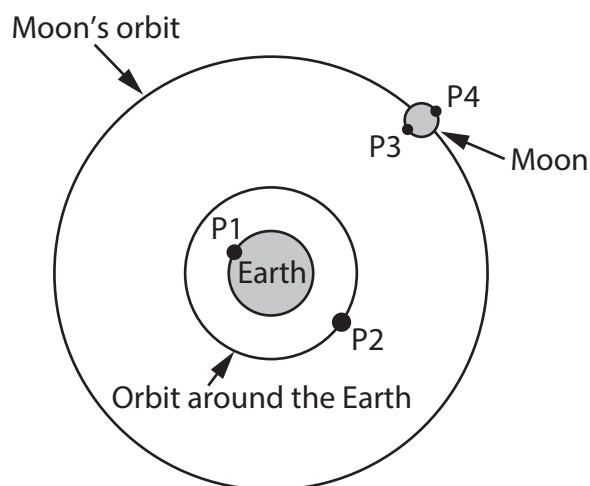
1

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2

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(b) Figure 13 shows the Moon's orbit around the Earth.



Position	Description
P1	Earth's surface
P2	Orbit around the Earth
P3	Near side of the Moon
P4	Far side of the Moon

(Not to scale)

Figure 13

A new ultraviolet telescope has been developed to observe the Sun on each day of the year.

Astronomers have suggested four positions for this new ultraviolet telescope.

These positions are labelled P1, P2, P3 and P4.

- (i) State **one** observational reason why P1 is an **unsuitable** position for the proposed ultraviolet telescope.

(1)

- (ii) The telescope needs to observe the Sun on each day of the year.

Analyse Figure 13 in order to explain whether P2, P3 or P4 would be a suitable position for the proposed ultraviolet telescope.

(3)



(c) Table 6 shows some data for a telescope used by a school.

Focal length		Magnification	Field of view (°)
Eyepiece (mm)	Objective element (cm)		
10	50.0	50.0	0.90
15	50.0	33.3	1.35
.....	50.0	25.0	1.80
30	50.0	16.7	2.70
50	50.0	4.50

Table 6

(i) Complete Table 6 by filling in the **two** missing numbers.

Use information from the Formulae and Data Sheet.

(2)

(ii) A student wishes to improve the telescope's images of Saturn.

The student replaced the telescope's eyepiece with an eyepiece that had a shorter focal length.

State **one** advantage of using an eyepiece with a shorter focal length.

(3)

State **two** disadvantages of using an eyepiece with a shorter focal length.

1

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2

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(Total for Question 8 = 13 marks)

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9 (a) (i) State **two** differences between the construction of optical telescopes and radio telescopes.

(2)

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2

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(ii) The sign below is displayed outside a radio telescope observatory.



Give **one** reason for this sign.

(1)

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(b) Modern astronomical observations are often recorded using a digital sensor.

One example of a digital sensor is a CCD (charge-coupled device).

Figure 14 compares the proportion of light detected by a CCD with the proportion of light detected by the human eye.

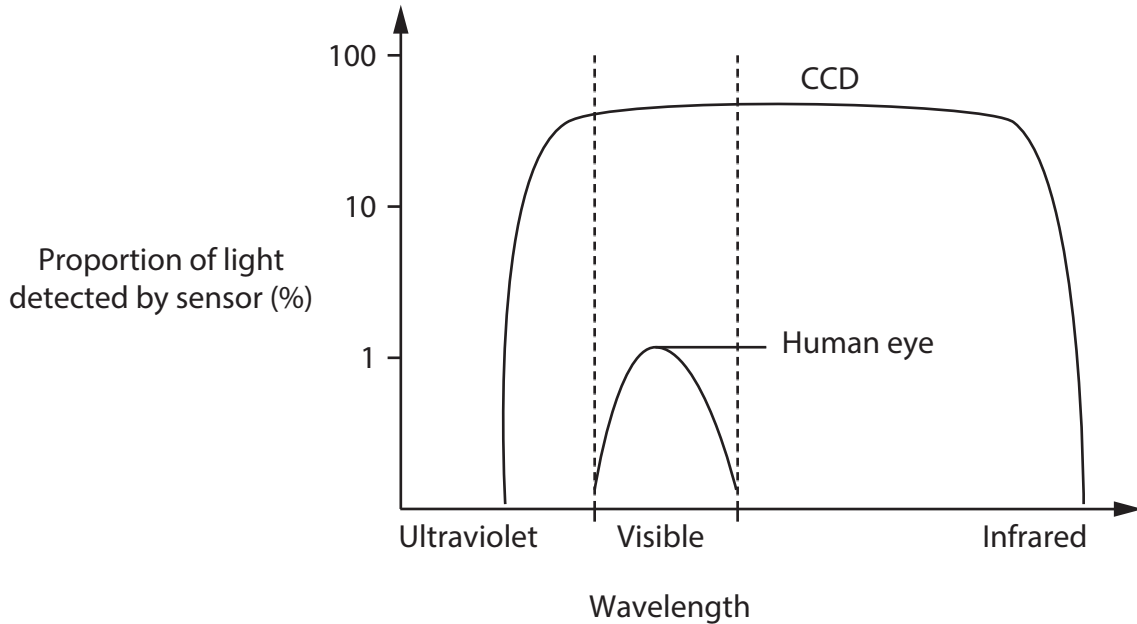


Figure 14

(i) Give **one** reason why CCDs are **not** used as sensors for radio astronomy.

(1)

(ii) Analyse Figure 14 in order to comment on the differences between a CCD sensor and the human eye.

(2)



(c) A GCSE Astronomy student decides to use a photograph to determine the radiant point of a meteor shower more accurately.

Figure 15 shows the photograph taken by the student.



Figure 15



The student concludes that the photograph is not suitable for determining the radiant point.

Evaluate ways to improve the photograph in order to locate the radiant point more accurately.

(6)

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Area with horizontal dotted lines for writing.

(Total for Question 9 = 12 marks)



10 (a) Figure 16 shows images of two galaxies.

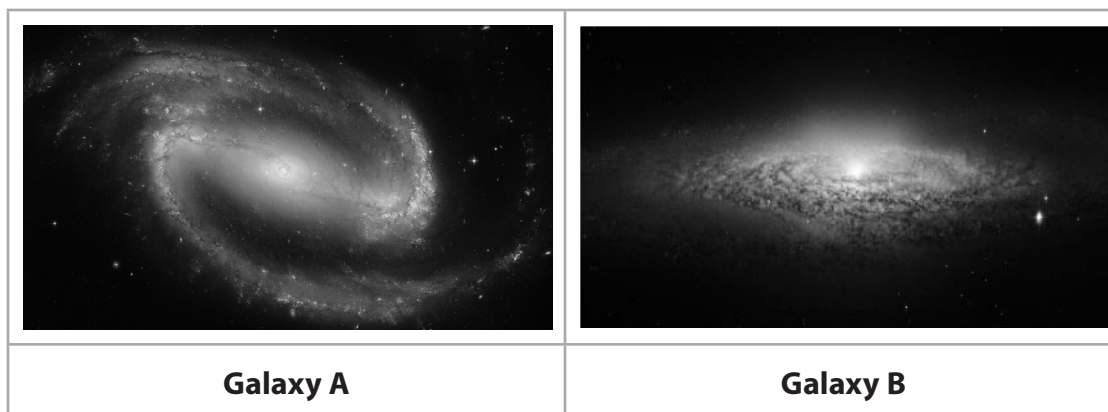


Figure 16

(i) State the Hubble classification of Galaxy A in Figure 16. (1)

(ii) Explain why it is difficult to determine the Hubble classification for Galaxy B in Figure 16. (2)

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(b) The distance to a galaxy can be determined by measuring its apparent size. Astronomers conclude that galaxies that appear smaller are further away.

(i) State **one** assumption that they have made. (1)

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(ii) A galaxy has an apparent angular diameter of 40 arcminutes (40').

Calculate the distance to this galaxy.

Use the equation:

$$\text{distance to galaxy (pc)} = \frac{\text{average size of a galaxy (pc)}}{\text{angular diameter of galaxy (}^\circ\text{)}} \times 60$$

Take the average size of a galaxy to be 50 000 pc.

Give your answer in Mpc.

(3)

Distance to galaxy = Mpc

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(c) The redshift of a galaxy can be determined from observations of the spectral lines in the light from the galaxy.

(i) Describe how astronomers obtain the patterns of spectral lines in the light from a galaxy.

You may include a clearly labelled diagram in your answer.

(2)

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(ii) Describe how astronomers measure the redshift of a galaxy by studying the spectral lines in the light from the galaxy.

(2)

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- (iii) Measurements of galactic distances and galactic redshifts can be used to determine a value for the Hubble Constant, H_0 .

Complete the sketch graph in Figure 17 to show how astronomers have determined a value for the Hubble Constant using these measurements.

(3)

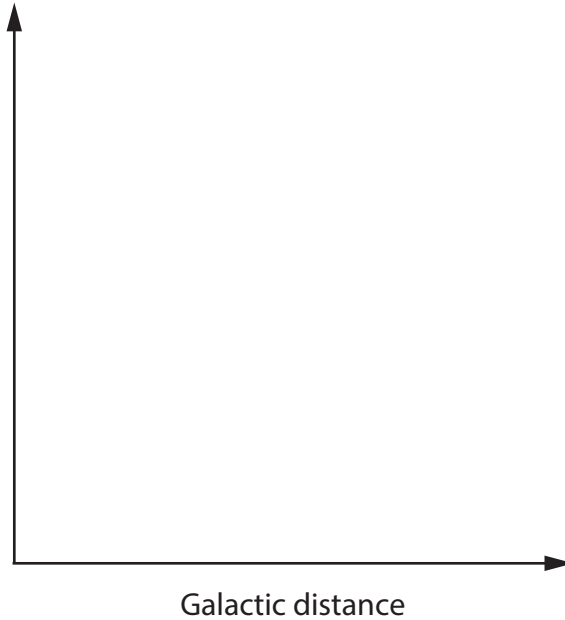


Figure 17

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 100 MARKS

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Image credits:

Figure 4 - NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration

Figure 5 - https://apod.nasa.gov/apod/image/1705/m13s_3Block.jpg

Figure 6 - <https://apod.nasa.gov/apod/image/1711>

Figure 7 - https://sservi.nasa.gov/wp-content/uploads/2013/10/3d_normalized_mosaic.8bit.png and <https://media.sciencephoto.com/image/c0103862/800wm/C0103862.jpg>

Figure 8 - <https://map.gsfc.nasa.gov/media/121238/index.html>

Figure 11 - NASA, <https://solarscience.msfc.nasa.gov/interior.shtml>

Figure 12 - © NASA

Figure 16 - © NASA

