DF
2015, Nov. 5

Write your name here

Surname	Other names

Pearson Edexcel GCSE

Centre Number | Candidate Number

Astronomy

Unit 1: Understanding the Universe

Suggested answers

Friday 15 May 2015 – Afternoon
Time: 2 hours

Paper Reference
5AS01/01

You must have:
Calculator, ruler

Total Marks

Ladies and Gentlemen,

The enclosed suggested answers should be studied in conjunction with the Mark Scheme and the Examiners' Report, issued by the Board.

I appreciate that you would not have the time to copy my answers. However, with your best interests in mind, I urge you to study the extended treatment attached to each solution, the so-called "JF²" supplementary material, designed to provide you with a more rigorous understanding of the topics. Perhaps you could find the time to highlight any elaboration which commands your particular attention?

It would be impossible for me to exaggerate the fact that the extra notes are truly an integral part of the studies that we share.

2

2

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. 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) Which of the following astronomical objects is closest to the Earth?

(1)

☐ **A** Mercury

☐ **B** Mars

☒ **C** The Moon

☐ **D** The Sun

(b) Which of these astronomical objects has the largest diameter?

(1)

☐ **A** Earth

☐ **B** Jupiter

☐ **C** The Moon

☒ **D** The Sun

(c) What is the approximate value of the Astronomical Unit?

(1)

☐ **A** 150 000 km

☐ **B** 150 000 miles

☐ **C** 150 000 000 km

☒ **D** 150 000 000 miles

In our lessons, we always use: 1.5×10^{11} m

(d) Which of these types of electromagnetic radiation is unable to penetrate the Earth's atmosphere?

(1)

☐ **A** microwaves

☐ **B** radio waves

☐ **C** visible light

☒ **D** X-rays

P 4 4 3 7 1 A 0 2 3 2

(e) The Earth and the planet Venus are of similar size but their atmospheres are very different. Give the name of the **most common** gas found in the atmospheres of:

(i) Earth

Nitrogen **(1)**

(ii) Venus

Carbon Dioxide **(1)**

(Total for Question 1 = 6 marks)

2 (a) Figure 1 shows a sketch of a comet.

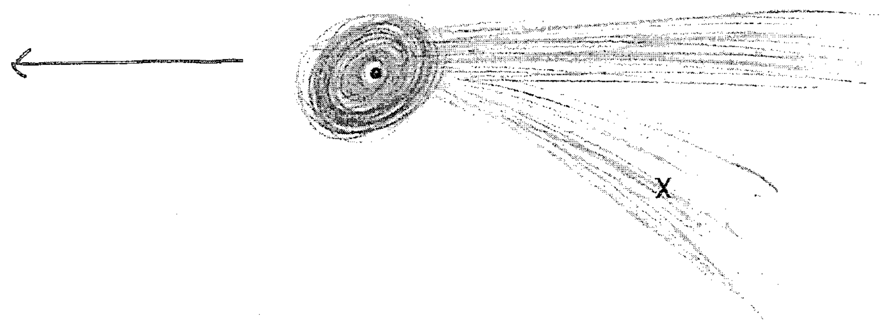


Figure 1

(i) What is the name of the curved tail labelled X?

(1)

☒ **A** dust tail

☐ **B** gas tail

☐ **C** ion tail

☐ **D** vapour tail

The dust tail: due to light reflected and scattered from small dust particles that were ejected from the comet and are now orbiting the Sun.

(ii) On Figure 1, draw an arrow to show the direction of the Sun.

(1)

(b) (i) Meteors are visible when small particles burn up as they pass through the Earth's atmosphere. What is the name of these particles?

(1)

☐ **A** fireballs

☐ **B** meteorites

☒ **C** meteoroids

☐ **D** micrometeorites

(ii) Why do annual meteor showers occur on roughly the same date every year?
You may use a labelled diagram in your answer.

(2)

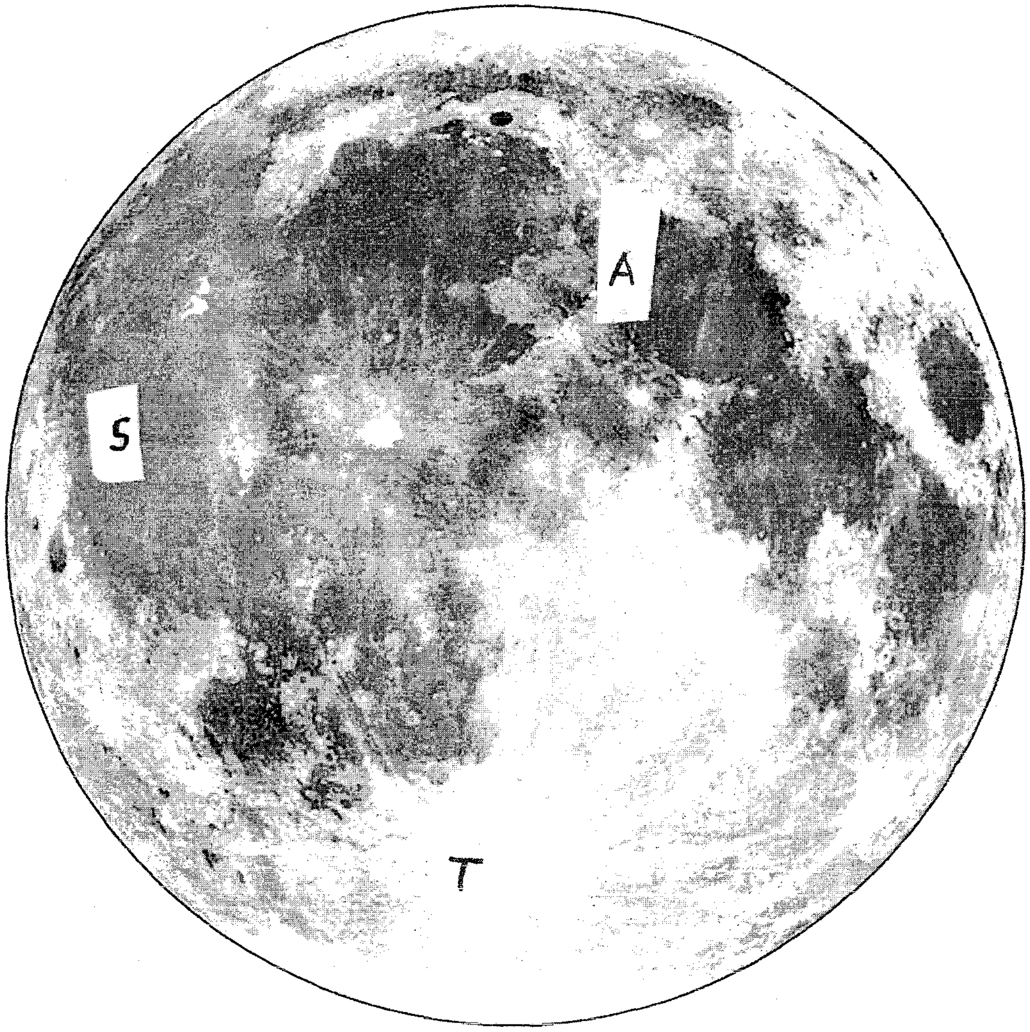
Please refer to my detailed answer to 10 (a) (iii) of the 2014 Paper (p. 18). It is part of the JF^2 amplification on the lower part of the page. In my opinion, a good answer to this question is worth more than two marks.

(Total for Question 2 = 5 marks)

P 4 4 3 7 1 A 0 5 3 2

Turn over

3 (a) Figure 2 shows the Moon's nearside.



(Source: © NASA)

Figure 2

On Figure 2, indicate the location of the:

(i) Ocean of Storms (Use the letter **S**)

(ii) Apennine mountains (Use the letter **A**)

(iii) Tycho crater (Use the letter **T**)

(3)

7 7

(b) (i) The Moon's far side is not visible from the Earth. What did astronomers use to help obtain the first images of the Moon's far side?

(1)

☐ **A** ALSEPs package

☐ **B** balloon

☒ **C** space probe

☐ **D** telescope

(ii) State **one** way in which the Moon's far side is different from its nearside.

(1)

Higher albedo
more craters

(c) What is the value of the Moon's rotation period?

(1)

☒ **A** 27.3 days

☐ **B** 28.0 days

☐ **C** 29.5 days

☐ **D** 31.0 days

(Total for Question 3 = 6 marks)

4 (a) Which of the following is **not** in our Local Group?

(1)

☒ **A** 3C 273, a quasar

☐ **B** LMC, an irregular galaxy

☐ **C** M31, Andromeda Galaxy

☐ **D** M33, Triangulum Galaxy

(b) (i) There are numerous types of **active galaxy**. Name **two** of these types.

(2)

Seyfert galaxy
1 Radio galaxy
2 Quasar

BL Lacertae. Objects appear star-light, as do quasars, but show no spectral lines.

(ii) State **one** way in which an active galaxy is different from a normal galaxy.

(1)

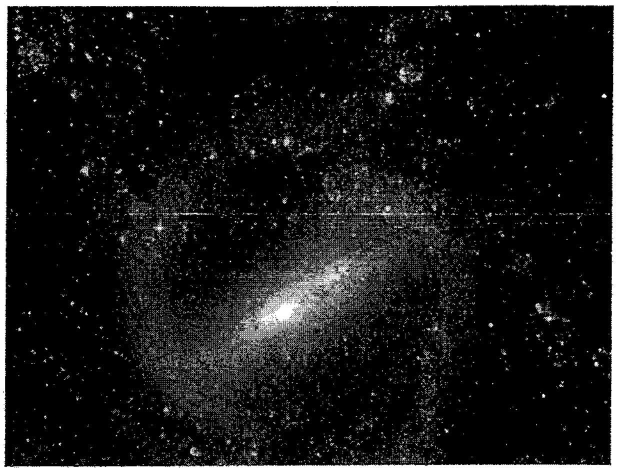
Normal galaxies (~ 98%) tend to have unvarying luminosities. Active galaxies are characterized by an unusually high (and possibly variable) luminosities, which appear to be non-stellar in origin.

JF²

Active galaxies seem to be quite rare. (I believe) only two have been found among the several hundred galaxies in the region of space extending to the Virgo cluster. We have been aware of these objects for between 30 and 40 years, and the galaxies have been around for 10^{10} years. The fact that only a small percentage is observed can be explained by supposing that, for the same, small percentage of the lifetime of each galaxy, it is active. The engine that powers the Active Galactic Nucleus, the tiny nucleus, has to power $(10^{11} \times P_{\odot})$ in a region little larger than the Solar System. It is proposed that the engine consists of an accreting massive black hole.

9

(c) (i) Figure 3 shows a galaxy.



(Source: © NASA)

Figure 3

What type of galaxy is shown in Figure 3?

(1)

☒ **A** barred spiral

☐ **B** elliptical

☐ **C** irregular

☐ **D** lenticular

(ii) What type of galaxy is the Milky Way?

(1)

☐ **A** elliptical

☐ **B** irregular

☐ **C** lenticular

☒ **D** spiral

(Total for Question 4 = 6 marks)

10

5 (a) What is the temperature of the Sun's photosphere? **(1)**

- ☐ **A** 5400 K
- ☐ **B** 5600 K
- ☐ **C** 5800 K
- ☒ **D** 6000 K

clearly, the difference between using the Celsius scale and the kelvin scale becomes less significant as the "level of hotness" rises.

(b) What is the approximate rotation period of the Sun at its poles? **(1)**

- ☐ **A** 20 days
- ☐ **B** 25 days
- ☐ **C** 30 days
- ☒ **D** 35 days

Sunspots are indicators of Solar rotation. At the solar equator, the sidereal period is just under 26 days, and around 30 days at a latitude of 60°. An example of differential rotation.

(c) Which of these solar features has the lowest temperature? **(1)**

- ☐ **A** chromosphere
- ☐ **B** corona
- ☐ **C** photosphere
- ☒ **D** sunspot

About 2000 degrees cooler than the photosphere. Therefore, they appear darker by contrast.

(d) Which is the most common element found in the Sun? **(1)**

- ☐ **A** helium
- ☒ **B** hydrogen
- ☐ **C** oxygen
- ☐ **D** sodium

Throughout most of its interior, the Sun is: 73% Hydrogen, 25% Helium and 2% everything else, by mass. (See the footnote)

(e) Which type of diagram do astronomers use to determine the length of the solar cycle? **(1)**

- ☐ **A** Butterfly Diagram
- ☐ **B** Hertzsprung-Russell Diagram
- ☐ **C** Messier Diagram
- ☐ **D** Tuning Fork Diagram

In the central 30%, or so, of its radius, the percentage of Hydrogen is increasingly depleted (and Helium compensatingly increased). At the core, half of the Hydrogen initially present has been converted into Helium.

(f) What is the name given to the continuous stream of charged particles moving away from the Sun?

(1)

☐ **A** solar eclipse

☐ **B** solar flare

☐ **C** solar maximum

☒ **D** solar wind

The Solar Wind: a gusty stream of high-speed particles that spread from the Sun, carrying with it traces of the magnetic field of the Sun.

(Total for Question 5 = 6 marks)

JF[2]

In addition to episodic coronal mass ejections, there is a continuous outflow of solar material that is termed the Solar Wind. The existence of a low-density, yet high-speed Solar Wind was proposed in 1951 by Ludwig Biermann, as a result of a study of the observed shapes of the tails of comets.

The existence of the Solar Wind was confirmed directly by measuring its flow using experiments on Russian and American space probes in the mid-1960s. The temperature of the Solar Wind, typically $> 10^5$ K, which leads to the gas being highly ionized and hence forming a plasma. Its composition is dominated by electrons and protons, with a small fraction of Helium nuclei. The speed of the Wind is typically several hundred km s^{-1}. Its number density in the vicinity of the Earth is $7 \times 10^6\ m^{-3}$. Important in the formation of the Wind is the relatively high gas pressure in the corona.

6 The earliest official list of just 48 constellations was compiled almost 2000 years ago by Egyptian and Greek astronomers.

(a) This list did not include constellations that were visible from countries such as Australia in the southern hemisphere. Suggest a reason for this. **(1)**

Constellations that were visible from (say) Australia would not appear above the horizon of Egypt and Greece.

(b) Suggest why astronomers in countries such as China or India compiled different lists. **(1)**

These countries have different legends and folk stories in their cultures.

(c) There are now 88 recognised constellations and numerous asterisms. In what way does an asterism differ from a constellation? **(2)**

The name given to an easy-to-remember group of stars generally but not exclusively, within a constellation.

(d) Name an example of:

(i) an asterism **(1)**

The Plough (Ursa Major), the Teapot (Sagittarius) the Square (Pegasus) the Belt (Orion)

(ii) a constellation **(1)**

Aquarius (10) Boötes (13) Aries (39) Canis Major (43) Cygnus (16) Eridanus (6) Draco (8) Hercules (5)

(Total for Question 6 = 6 marks)

The numbers in the brackets (above) give the order of size out of the eighty-eight constellations, with '1' the largest.

Hydra (Water Snake) = 1
Orion (Hunter) = 26
Cassiopeia (Queen) = 25
Equuleus (Little Horse) = 87
Cetus (Whale) = 4
Aquila (Eagle) = 22
Gemini (Twins) = 30
Perseus (Perseus) = 24
Pegasus (Flying Horse) = 7
Taurus (Bull) = 17

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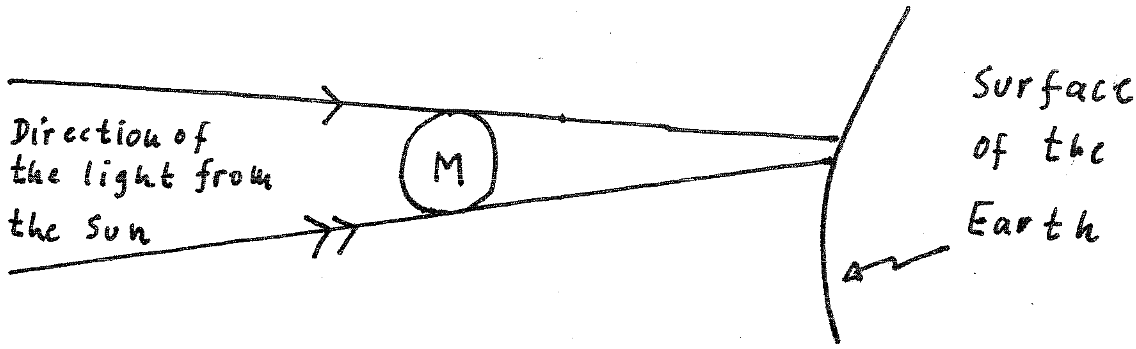
7 (a) Draw a labelled diagram to show the relative positions of the Sun, Earth and Moon during a total solar eclipse.

(2)



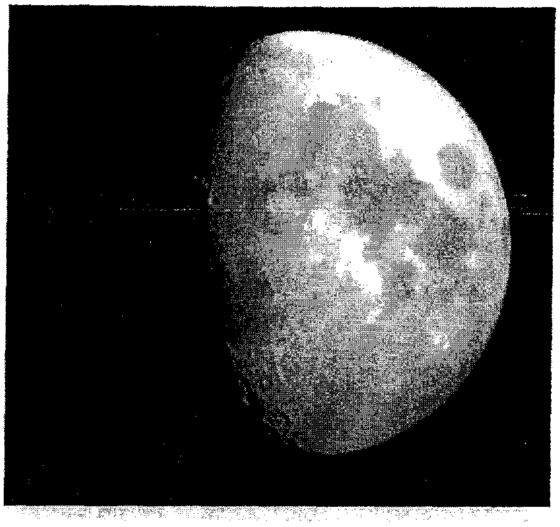
(b) Explain why solar eclipses do not occur every month.

(2)

Once a month, when the phase of the Moon is New, it usually passes through the sky in a direction almost the same as the Sun, because the orbital inclination of the Moon makes angle of 5·09° with the plane of the

Solar System. "Almost" is the key word here. However, there are occasions when the Sun, Moon and the Earth lie in a straight line. By a lucky coincidence, the Moon and the Sun subtend the same angle at the Earth: although the Sun is four hundred times the diameter of the Moon, it is four hundred times farther away. The result is that when the "lining-up" is exact, the Moon can just obscure the bright surface of the Sun, so producing a total Solar Eclipse. An annular (not annual) —— from the Latin "annulus" —— occurs when the lining-up is exact, but the Moon is at perigee, subtending a slightly smaller angle.

(c) Figure 4 shows a photograph of the Moon.



(Source: © Nigel Marshall)

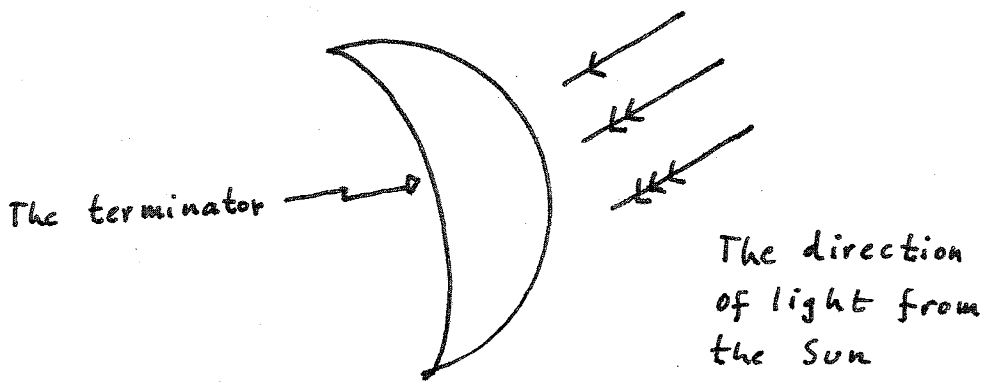
Figure 4

(i) What phase of the Moon is shown in Figure 4?

"Gibbous", meaning hunch - backed. **(1)**

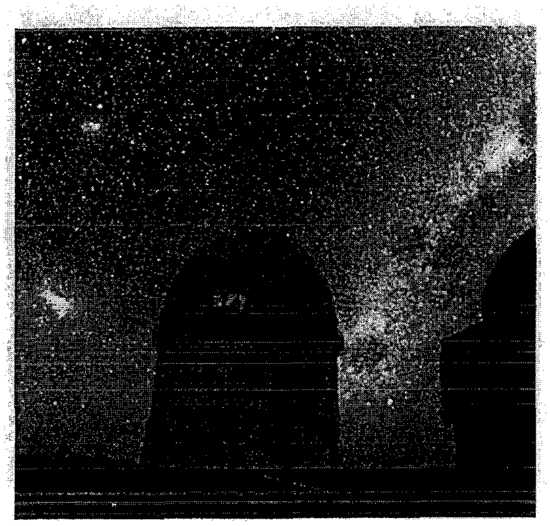
(ii) Sketch how the Moon would have appeared 8 days earlier.

(1)



(Total for Question 7 = 6 marks)

8 Figure 5 shows a photograph of the Milky Way, taken at an observatory in the southern hemisphere.



(Source: © Roger Smith/NOAO)

Figure 5

(a) On a clear night when there is very little light pollution, the Milky Way appears as a faint band of light across the sky.

(i) Name **one** source of light pollution. (1)

* Street lighting

(ii) Why does the Milky Way appear as a band? (1)

We are looking in a direction towards the centre of the Galaxy, confined to a thin plane.

(iii) Figure 5 shows some dark patches within the Milky Way. Suggest the nature of these dark patches. (1)

Interstellar (between the stars), such as dust

(b) State **two** ways in which a pair of binoculars or a small telescope improve an observer's view of the Milky Way. (2)

Greater resolution for seeing individual stars.

1 More light energy is gathered ∴ brighter images.

2

* "Pollution" implies sources of light which are not natural. Therefore, I exclude the Moon and the Aurorae →

(c) Figure 5 also shows two small galaxies that are companions to the Milky Way.
Name **one** of these galaxies.

(1)

The Small / Large Cloud of Magellan.

(Total for Question 8 = 6 marks)

JF²

In the south of the sky, not visible from Europe, are the two clouds of Magellan, which are conspicuous, naked-eye objects —— that look like broken-off parts of the Milky Way Galaxy (our Galaxy). Both are with 70 000 pc (70 kpc) and seem to be satellites of our Galaxy, though they are much smaller.

For example, the L.M.C., as it is usually known, was the site of a supernova observed in February, 1987. Radiation from this event encountered a ring of gas surrounding the supernova and caused it to brighten. The ring had been blown off by the supernova progenitor, thousands of years earlier, and has been expanding ever since. Observations have placed the L.M.C. just beyond the Milky Way.

I cannot understand the reasoning behind the description: "Shark-infested waters." Surely, that is where the sharks belong —— it is their evolutionary habitat! Where else should they be?

An infestation of field mice inside a house is a different matter.

9 (a) A group of astronomers are currently constructing a scale model in which the Solar System has been reduced to the size of the British Isles. In this model, the Earth is 10 km away from the Sun.

(i) Which **two** planets would be represented by models placed closer than 10 km from the Sun?

(1)

Mercury and Venus

(ii) The planet Jupiter is 5.2 AU from the Sun. How far in km would the model representing Jupiter be from the model Sun?

(1)

10 km ≡ 1 A.U.

∴ 5.2 A.U. ≡ 52 km

(iii) The model of Saturn is 95 km from the model Sun. How far in AU is the planet Saturn from the Sun?

(1)

9.5 A.U.

(b) A teacher created a different scale model in her classroom. She used a sphere of diameter 1.0 m to represent the Sun.

(i) What diameter of sphere should the teacher use to represent the Earth?

(1)

- ☐ **A** 0.5 cm
- ☒ **B** 1.0 cm
- ☐ **C** 5.0 cm
- ☐ **D** 10 cm

(ii) In another model, the planet Neptune was 150 m from the Sun. If the actual distance from Neptune to the Sun is 30 AU, calculate the distance from the Sun to the Earth in this model.

(3)

150 m ≡ 30 A.U.

∴ 1 A.U. ≡ 5 m

(Total for Question 9 = 7 marks)

Reminder: The symbol ≡ means "equivalent to", to use = ("equal to") would be ridiculous.

P 4 4 3 7 1 A 0 1 8 3 2

10 Nigel and Ruth were observing the stars around Polaris from a latitude of 58°N.

(a) (i) State the declination of Polaris (to the nearest degree). **(2)**

+ 90°

(ii) What is the angle of elevation of Polaris when observed from this site? **(1)**

58° It is always equal to the observer's latitude

(b) Ruth noticed that the stars around Polaris had moved during the course of 2 hours. What is the reason for this apparent motion? **(1)**

The rotation of the Earth

(c) Nigel observed a constellation and deduced that none of its stars would set below the horizon. What name is given to stars that never set as seen from a given location? **(1)**

Circumpolar

(d) State whether a star of declination +34° would set from this latitude.

Use the formula

declination > 90° – latitude. **(1)**

No. See the explanation below.

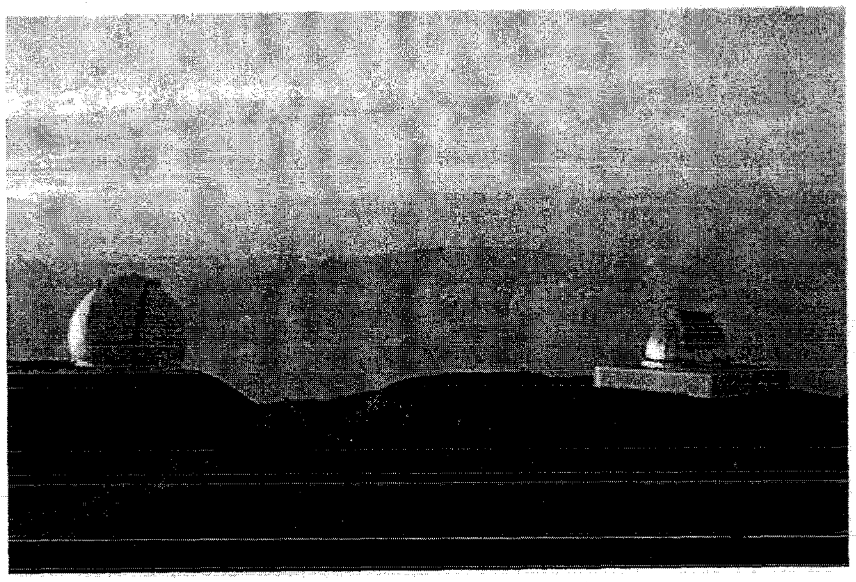
(Total for Question 10 = 6 marks)

We can always find out which stars will be circumpolar and which stars will not. From part (ii) above, Polaris will be 58° above the horizon (if we neglect its slight displacement from the Celestial pole).

It follows that the distance between Polaris and the overhead point, or angular zenith distance is (90° – 58°) = 32°. From latitude + 58°, then, a star will be circumpolar if its declination is (90° – 58°) = 32°, or greater.

Clearly, this star is circumpolar.

11 (a) Figure 6 shows NASA's infrared observatory near the summit of Mauna Kea on Hawaii.



(Source: © NASA)

Figure 6

(i) Give **one** reason why infrared observatories are located on high mountains. (1)

To reduce atmospheric turbulence (improve "seeing")
To reduce the effects of refraction.

(ii) Name **two** gases in the Earth's atmosphere that absorb large amounts of infrared radiation. (2)

1 Water vapour *

2 Methane

(b) (i) The Earth's atmosphere has some benefits for humans. State **two** of these benefits. (2)

1 Protection from ultra-violet radiation.

2 Renders most meteoroids harmless.

(ii) In addition to absorbing infrared radiation, the Earth's atmosphere has further drawbacks for astronomers. State **one** of these drawbacks. (1)

The attenuation of light.
Impairs "seeing" conditions.

(Total for Question 11 = 6 marks)

* How is a gas distinguished from a vapour? The difference is important.

(b) (ii) Provides our nice blue skies. Surely, this is a legitimate benefit?

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22

12 (a) Figure 7 shows the light curve for a Cepheid variable star.

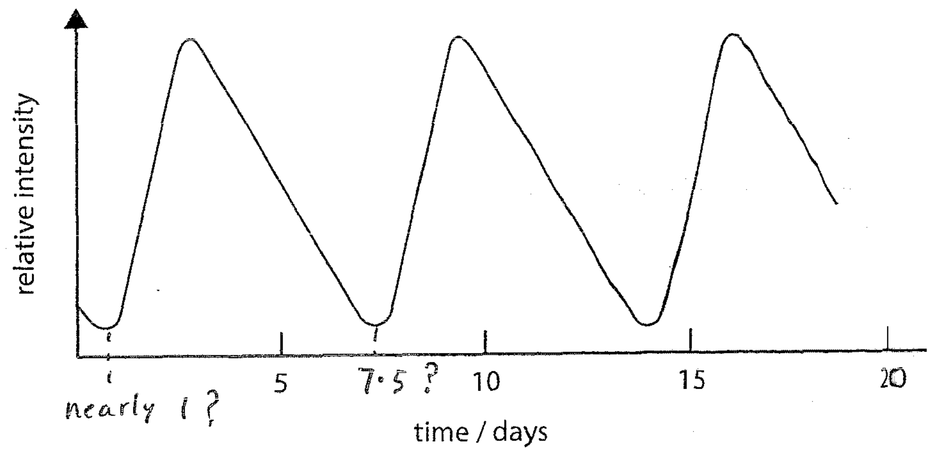


Figure 7

(i) Use Figure 7 to determine the time period to the nearest day of this Cepheid variable. **(2)**

seems to be around 7 days

(ii) Explain how astronomers determine the distance to a Cepheid variable star. **(3)**

Cepheids are giant stars, and are common in the Galaxy. What makes them so important is that their periods are linked with their luminosities (Units W or J s⁻¹). That is, for example, a Cepheid with a period of 5·3 days will have the same luminosity as any other Cepheid with a 5·3 day period. The longer the period, the greater the luminosity. The best-known member of the class is Delta Cephei, in the far North of the sky. The range is from magnitude 3·5 to 4·4. Thus Eta Aquilae, in the Eagle constellation, a Cepheid with a period of 7·2 days, is more luminous / powerful than Delta Cephei.

Cepheids are typically 5 → 20 times more massive than the Sun and up to 30,000 times →

 22(a)

as luminous as the Sun. They can vary on timescales of days to months, during which their radii change by almost one third. Their brightnesses and predictable variability means that they can be seen out to distances of 100 million light years (30×10^6 pc).

Cepheid variables were discovered in 1784 and are named for the prototypical star, Delta Cephei (δ Cephei). A better-known example is Polaris, the North Star. The period-luminosity relationship was discovered in 1908 by Harvard astronomer Henrietta Swan Leavitt, based on Cepheids observed in the Magallenic Clouds. These stars were a critical part of the jigsaw puzzle in establishing the size of the Milky Way, and the distances to the galaxies beyond our own.

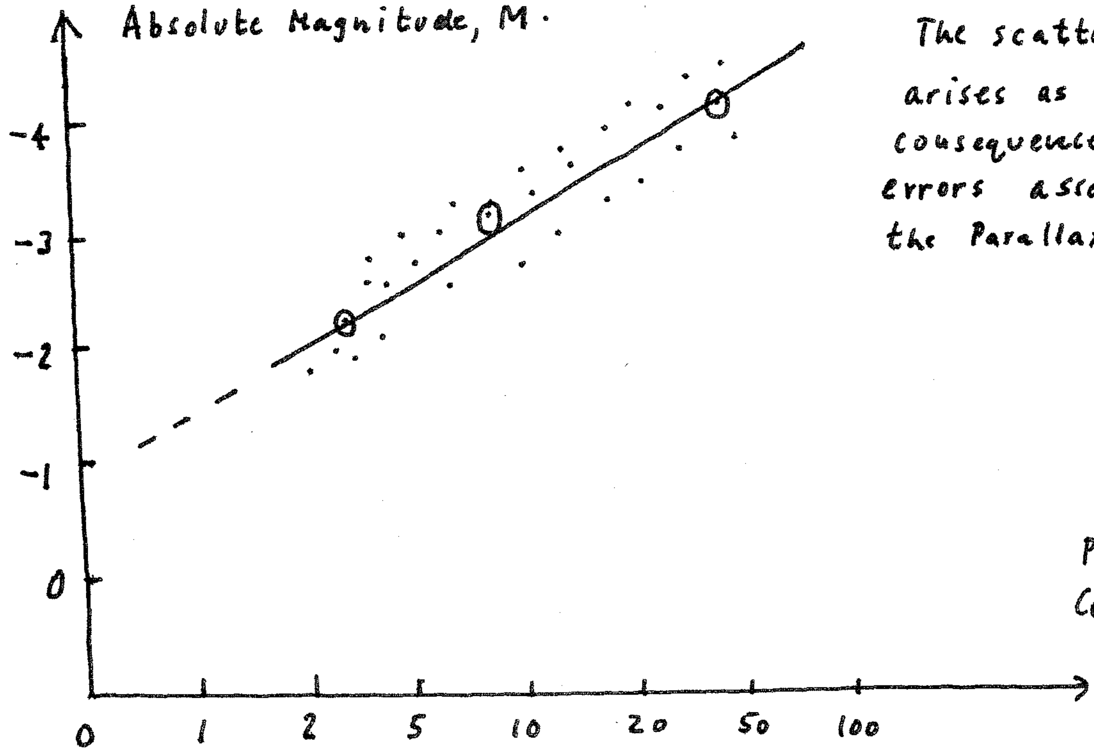
Henrietta Leavitt's work showed a vitally important aspect about Cepheids: that there is a link between their Absolute Magnitudes (the magnitudes they would have at a distance of 10 pc) and their periods.

Suppose the distance of a Cepheid is measured using the Parallax Method. The Apparent Magnitude, m, can also be measured. Using the inverse-square law, we can calculate what would be the magnitude of the star were it at a distance of 10 pc, its Absolute Magnitude, M.

The calibration chart has the following general

→

form :



The scattering arises as a consequence of the ± errors associated with the Parallax measurement

- Measure the Heliocentric Parallax of the Cepheid variable star, and use this to calculate its distance, d, in parsecs, having already measured its Apparent Magnitude, m.
- Calculate the magnitude of the star were it at a distance of 10 pc. This would be its Absolute Magnitude, M.
- The Period can then be related to its Absolute Magnitude

If the star is farther than 10 pc, its Absolute Magnitude will be greater than its Apparent Magnitude; if the star is closer than 10 pc, its Absolute Magnitude will be less than its Apparent Magnitude.

Two stars which have the same Absolute Magnitudes (that is, they are equally bright at 10 pc) means that they have the same luminosities — their intrinsic properties (W or Js^{-1}), must be equal.

→

22(c)

The Board expects you simply to substitute M, m and d in the following so-called "Modulus Formula", because a knowledge of logarithms is beyond G.C.S.E.

d is in parsecs

$$M = m + 5 - 5\log_{10} d$$

← I hate this expression

Not in our lessons —— we shall use the inverse-square law, on which the Modulus Formula is based.

Remember, for a magnitude change of Δm, the consequent change in brightness, ΔB, are connected by

$$\Delta B = (2\cdot512)^{\Delta m}$$

When $\Delta B = 100$,

$\Delta m = 5$

That is,

$$100 = (2\cdot512)^5 = 2\cdot512 \times 2\cdot512 \times 2\cdot512 \times 2\cdot512$$

Comparing the Apparent Magnitudes of the Sun and the Moon.

$m_{Moon} \approx -12$

$m_{Sun} \approx -27$

$\therefore \Delta m = 15$

$\therefore$

$$B_{Sun} \approx (2\cdot512)^{15}$$

Use your R.T.C. here

$\approx$ times brighter than the Moon

(b) Figure 8 shows the light curve for an eclipsing binary star.

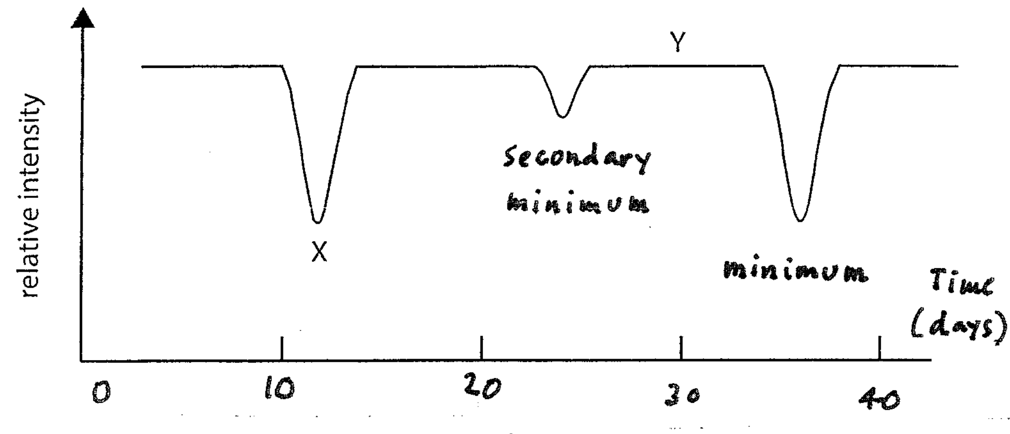


Figure 8

(i) The time period of this eclipsing binary is 26 days. Add the correct numbers to the horizontal scale to show this.

(1)

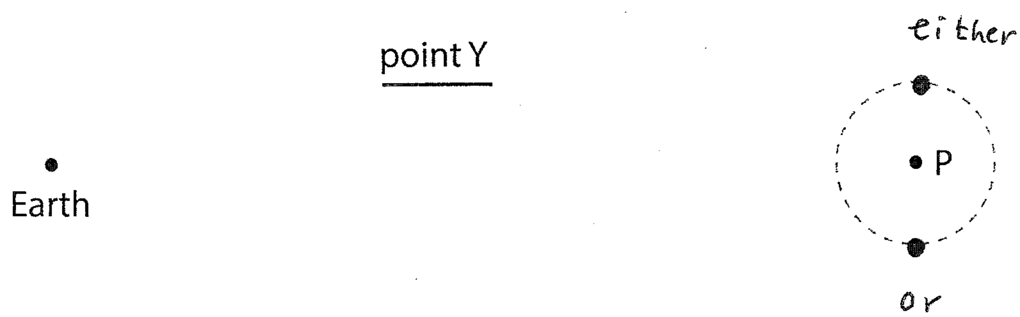
(ii) The binary star system consists of a brighter primary star (**P**) and a dimmer secondary star (**S**). The first diagram is for point **X** on the light curve (Figure 8) and the second diagram is for point **Y**. The dashed circles represents the orbit of the secondary star.

Complete the two diagrams below to show the position of the secondary star for points **X** and **Y** on Figure 8. Use the letter **S**.

(2)

point X

point Y



(Total for Question 12 = 8 marks)

13 (a) Figure 9 shows the orbit of a short-period comet around the Sun.

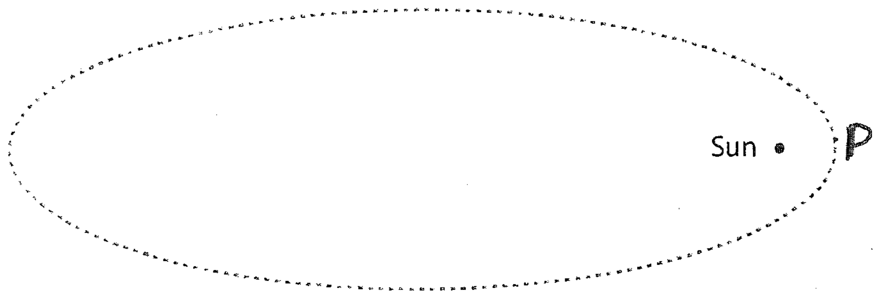


Figure 9

(i) On Figure 9 indicate the position of the comet when it is at perihelion. Use the letter **P**.

(1)

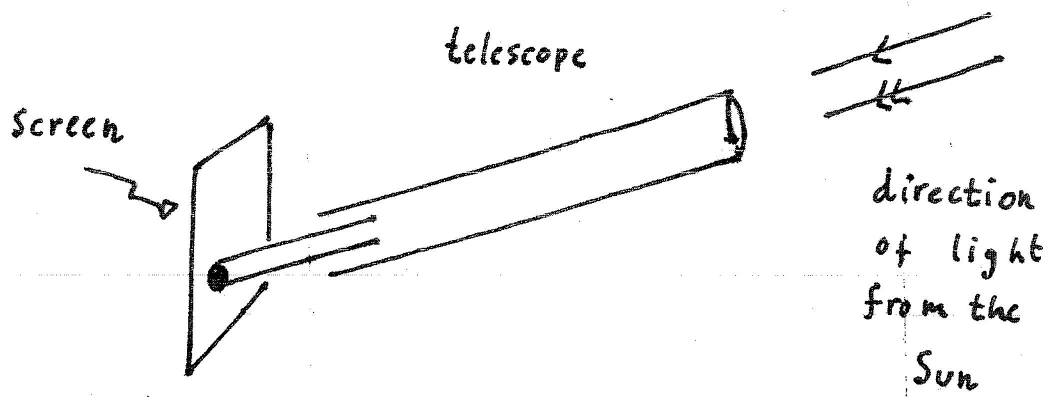
(ii) What is the name of the shape of this orbit?

(1)

elliptical

(b) In 2012 it was possible to observe a transit of the planet Venus. Describe how to observe a transit safely.

(2)



Under <u>no</u> circumstances should the Sun be observed directly, with or without optical aid.

Instead, project an image of the disc of the Sun onto a screen, in order to see the image of Venus crossing the circular image of the screen.

(c) Figure 10 shows the orbits of the Earth and Mars around the Sun.

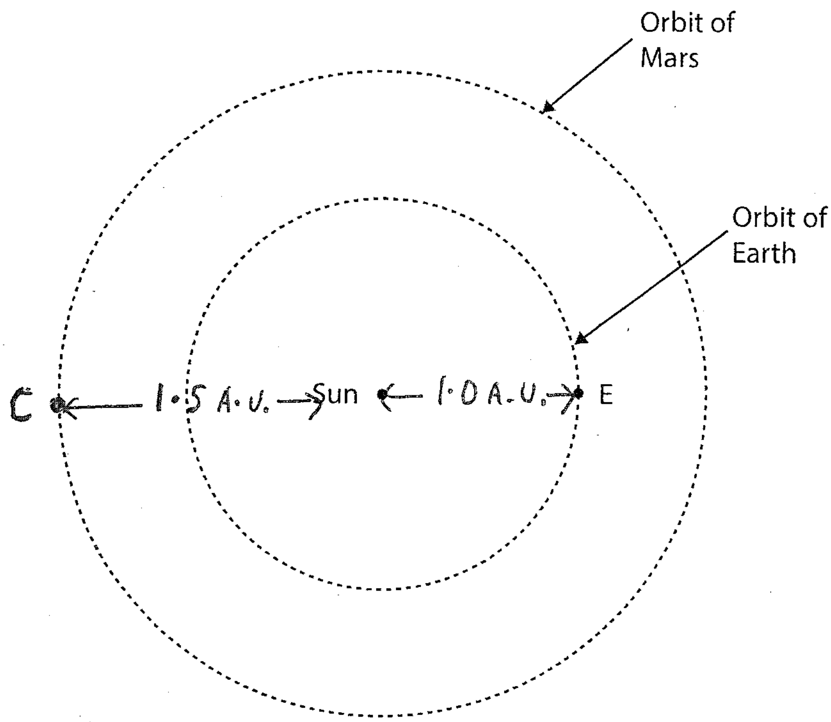


Figure 10

When the Earth is at position E, indicate the position of Mars when it is at **conjunction**. Use the letter **C**.

(1)

(d) The mean distance from Mars to the Sun is 1.5 AU.

(i) How far is Mars from the Earth when it is at conjunction?

(1)

2·5 A.U.

(ii) Calculate the orbital period of Mars.

Use the formula

$T^2 = r^3$

Give your answer to 2 significant figures and state the unit.

Using "$\frac{T_E^2}{R_E^3} = \frac{T_M^2}{R_M^3}$"

(Total for Question 13 = 8 marks)

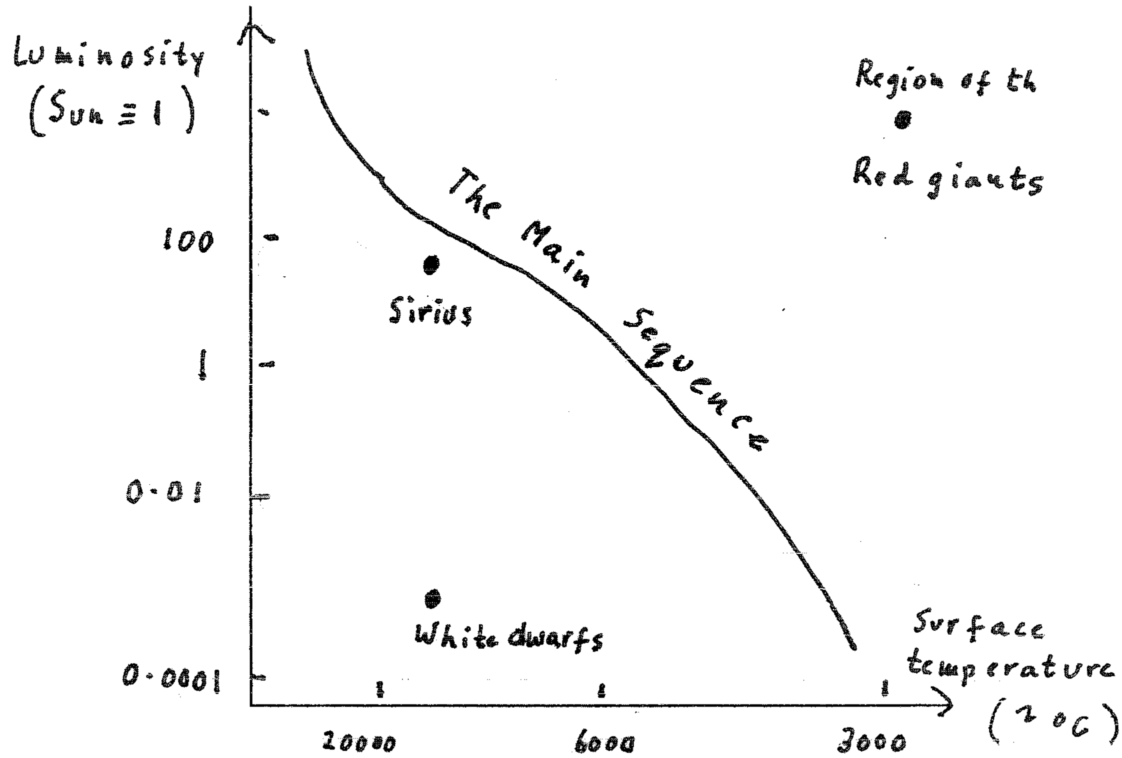
Substituting :

$\frac{(1yr)^2}{(1\ A.U.)^3} = \frac{T_M^2}{(1\cdot5\ A.U.)^3}$

Continued at the foot of p. 26

[Turn] over ▶

14 In the space below, draw a sketch of the Hertzsprung-Russell Diagram.



Label the axes.

Indicate and label the Main Sequence.

Indicate and label the locations of White Dwarf stars and Red Giant stars.

(Total for Question 14 = 5 marks)

Rearranging, to make T_M^2 the subject of the equation:

$$T_M^2 = \frac{(1\,yr)^2 \times (1{\cdot}5\ A.U.)^3}{(1\ A.U.)^3}$$

$$\therefore T_M = \left[\frac{(1\,yr)^2 \times (1{\cdot}5\ A.U.)^3}{(1\,A.U.)^3}\right]^{\frac{1}{2}} = 1{\cdot}8(3)\ yrs$$

26 (a)

Supplement to number 14

Danish astronomer, Ejnar Hertzsprung in 1905 and American astronomer, Henry Norris Russell in 1913, independently noted similar trends between the brightness (taking into account their luminosities and distances) and the colours of stars. Both astronomers are now recognised in the name of a diagram that plots the luminosities of stars against their colours: the Hertzsprung - Russell diagram (or HR for short).

On the HR diagram, 90 per cent of stars, including the Sun, lie a diagonal stripe that runs from bright, hot, blue stars to fainter, cool, red ones. This band is known as the Main Sequence, and that stars that fall along it as Main Sequence stars. In addition to the Main Sequence, other groups of stars are evident on the HR diagram. These include a branch of Red giants —— red stars of similar colours but a range of luminosities —— and a population of White dwarfs —— hot but faint stars, as well as a separate branch of Cepheid variable stars, with a range of colours but similar luminosities.

Such patterns hinted that stars must condense from the interstellar medium and evolve in consistent ways. It was not until the 1930s that astronomers understood the reason(s) that stars shine.

15 (a) Which of the following compounds is regarded by scientists as being essential to life?

(1)

- ☐ **A** ammonia
- ☐ **B** carbon dioxide
- ☐ **C** methane
- ☒ **D** water

*(b) Name and describe **one** method that astronomers use to detect exoplanets. You may draw a labelled diagram to support your answer.

(4)

① The regular dimming of a star, due to the transit of a planet in front of it.

② The presence of a planet orbiting a star causes the star to inscribe a small circle, due to the mutual gravitational force between them. This wobble can be detected by the Doppler shift in the light of the star.

Launched in 2009, NASA's Kepler spacecraft is designed to locate Earth-like planets. Its 0·9 m diameter telescope continually

name watches a large swath of sky

description (105 square degrees) that includes 100,000 stars.

The majority of exoplanets identified so far have been found using the Doppler method. This method is most sensitive to very large planets. The transit method can track more distant and smaller

(Total for Question 15 = 5 marks)

planets, but requires particularly sensitive measurements of the light from the star. This is best done from space, above the Earth's atmosphere.

16 (a) Explain what is meant by the term **redshift**.

(2)

Redshift is expressed in terms of the proportional change in the observed and emitted wavelength (or frequency) of the light from a receding object, using the spectral lines

*(b) Describe how quasars were discovered. Quasi-Stellar Objects (QSO)

(4)

During the 1960's a type of star caused particular puzzlement. Their unusual spectra (plural of spectrum) showed bright emission lines, but the lines did not seem to lie at the right wavelengths to be attributed to known elements. In 1965, a Dutch astronomer, Maarten Schmidt, realized that the lines did correspond to normal elements, but were heavily redshifted.

(Total for Question 16 = 6 marks)

These redshifts indicated that these "stars" lay at vast distances, well beyond the Milky Way and in the realm of the galaxies. Yet they did not look like fuzzy galaxies —— they were point sources of light. Furthermore, for the distances that their redshifts indicated, they were exceedingly luminous (radiated huge amount of energy every second). It was surprising that something which looked like one of the stars in our Galaxy was in fact located well beyond the Local Supercluster. That is, farther than any of the hundred, or so, galaxies that comprise the Local Group, which includes our Galaxy.

17 Table 1 lists the properties of five stars in a constellation.

star	apparent magnitude	absolute magnitude	spectral type
α	1.3	– 8.7	A
β	2.1	– 6.1	F
γ	2.8	– 1.8	G
δ	4.1	– 0.7	B
ε	6.9	– 2.3	K

Table 1

(a) How many times would star β appear brighter than star δ? **(1)**

$\Delta B = (2\cdot512)^{\Delta m} = (2\cdot512)^2 = \underline{6\cdot25}$

(b) Which is the faintest star that could be seen with the naked eye on a clear night? **(1)**

δ

(c) Give the Greek letter of the star which:

(i) is the hottest **(1)**

δ

(ii) is furthest to the right on a Hertzsprung-Russell Diagram **(1)**

ε

(iii) is the furthest away from us. **(1)**

α

Clue: look for the biggest difference between the Apparent and Absolute magnitudes

(Total for Question 17 = 5 marks)

Supplement to question 17.

The sequence of letters is alphabetically chaotic. I was particularly young when I learned the mnemonic:

"Wow, O Be A Fine Girl Kiss Me Right Now Sweetie | Slap"

It certainly helped me remember the order of the letters!

Each type is divided into ten divisions. Thus, for example, the Sun is G2; Rigel B8; Polaris F8; Aldebaran K5 and so on.

*18 Describe the discoveries of the two dwarf planets Ceres and Pluto. Name the astronomers who discovered them and the method of discovery.

Ceres Pronounced "series"

discoverer Discovered by G. Piazzi, a Sicilian (1801)

method of discovery

Beyond the orbit of Mars there is a wide gap before Jupiter is reached. Astronomers of the eighteenth century suspected that there might be a planet inside this gap. Ceres was discovered during a telescopic Search for Neptune.

Pluto

discoverer Clyde Tombaugh in 1930

method of discovery

Even after the discovery of Neptune in 1846, all was not well with astronomers' conclusions about the movements of the outer planets. Slight irregularities remained, suggesting perturbations

(Total for Question 18 = 5 marks)

due to a body beyond Neptune. The discovery by Tombaugh was actually a fluke, since Pluto, with so little mass, Should not have caused the apparent perturbations of Neptune. The planet was named after the God of the Underworld, because of its tremendous distance from the Sun

Clyde Tombaugh's discovery was made using two 14 x 17 inch photographic plates between January 23 and January 30, 1930. It is truly quite incredible that, with the so-called "Blink Microscope," he detected that one of the faint images had changed its position relative to the dozens of the Surrounding stellar images, over a time interval of one week.

Please, could you Google the Blink Microscope for me?

19 A group of students were observing the night sky from the Isle of Skye in Scotland. Table 2 gives the coordinates of some of the stars that they observed.

Data for some of the stars

star	Right Ascension	declination / °
α	20 h 45 min	+45
β	19 h 30 min	+27
γ	20 h 20 min	+40
δ	19 h 45 min	+42

Table 2

(a) Give the Greek letter of the star that appeared:

(i) furthest east

α

(1)

(ii) highest in the sky. α The greatest angular distance measured from the Celestial Equator.

(1)

(b) The students recorded the culmination of star β at 23:00 GMT.

(i) What is meant by the term **culmination**?

The maximum altitude of a celestial body above the horizon.

(1)

(ii) At what time (GMT) did star α culminate on the same night?

00 : 15

(1)

(iii) At what time (GMT) would star β culminate two nights later?

22 : 52

(2)

(Total for Question 19 = 6 marks)

Reminder: The rotational period of the Earth is 23h 56m. This means that if a star culminated (due South) at (say) 20:50 on a given night, it would reach its highest point at 20:46 the following night, and 4 minutes earlier on each succeeding night.

20 (a) Data for a spectral line in the light from a distant galaxy are given below.

observed wavelength = 420 nm

rest wavelength = 380 nm

Calculate the radial velocity of the galaxy

Use the formula

$$\Delta\lambda \text{ (change in } \lambda) = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c}$$

Rearranging to make v the subject of the equation.

$$v = \left(\frac{\lambda - \lambda_0}{\lambda_0}\right) \times c$$

The speed of light is 300 000 km/s.

Give your answer to 2 significant figures and give the unit.

(3)

That is,

$$v = \left(\frac{\lambda - \lambda_0}{\lambda_0}\right) \times c = \left(\frac{40 \text{ nm}}{380 \text{ nm}}\right) \times c = 0.105 \times 3 \times 10^5 \text{ km s}^{-1}$$

$$\approx 3.1(5) \times 10^4 \text{ km s}^{-1}$$

(recessional)

(b) Astronomers determine that a different galaxy has a recession velocity of 1.2×10^5 km/s. Calculate the distance to this galaxy.

Use the formula

$v = Hd$ → Better: H_0

Rearranging: "$d = \frac{v}{H_0}$"

The subscript zero indicates the current value of H.

The Hubble constant is 77 km/s/Mpc.

Give your answer to 2 significant figures and give the unit.

(3)

substituting:

$$d = \frac{1.2 \times 10^5 \text{ km s}^{-1}}{77 \text{ km s}^{-1} (\text{Mpc})^{-1}}$$

$$= 1560 \text{ Mpc}$$

Parsec (pc) = 3.1×10^{16} m

$\therefore$ 1 Mpc = 3.1×10^{22} m

(Total for Question 20 = 6 marks)

TOTAL FOR PAPER = 120 MARKS

1 pc = 206,265 A.U.

Light-year (ly) = 63,240 A.U.

= 0.30660 pc

$\therefore$ 1 pc = 3.2616 l.y.

$H_0 = 77 \pm 7 \text{ km s}^{-1} (\text{Mpc})^{-1}$

It is better to refer to the Hubble Parameter, since it appears to be time-dependent