Eton College King's Scholarship Examination 2014

SCIENCE (SECTION 2 - DATA ANALYSIS) (30 minutes)

Candidate Number:_________________________

*Write your candidate number, **not your name**, in the space provided above.*

Read the information and answer the questions in the spaces and on the graph paper provided as appropriate.

You are expected to answer all the questions.

In questions involving calculations, all your working must be shown.

For examiners' use only.

Total [40]	

Our Solar System contains eight planets and many other objects – including dwarf planets, asteroids and comets – in orbit around the Sun.

(a) What is the shape of a planet's orbit around the Sun?

[1]

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(b) What force causes planets and other objects to orbit the Sun?

[1]

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Table 1 contains data relating to the Sun-centred orbits of five objects within our Solar System. The objects are not named.

Table 1

Object	Orbital Radius (in light-minutes)	Orbital Period (in days)
A	8.3	365
B	12.6	686
C	19.6	1325
D	23.0	1679
E	26.0	2029

Orbital radius is the average distance between the object and the Sun (that is, the radius of its orbital path). Orbital radius is given in **light-minutes**, to one decimal place. One light-minute is the distance travelled by light in one minute.

Orbital period is the time taken for the object to complete one full orbit. Orbital period is given in (Earth) **days**, to the nearest whole day.

(c) The speed of light is 0.30 million km/s. Calculate the value of one light-minute in millions of kilometres. Show your working.

[2]

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(d) Convert the orbital radius of object **E** into millions of kilometres. Show your working. **[2]**

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(e) The total distance between any two of the objects from the table changes over time. What is the maximum separation of objects **A** and **E**? Show your working.

[2]

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(f) Which of the objects **A-E** in Table 1 is Earth, if any? Explain your answer carefully.

[2]

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(g) On the following page, plot a neat graph of orbital period in days (on the *y* axis) against orbital radius in light-minutes (on the *x* axis) using the data from Table 1.

Your graph should include a point at the origin (0, 0).

Draw a line of best fit.

[5]

*Note that a line of best fit does **not** have to be straight; it is the line that best follows the trend of the points plotted.*

(h) What feature of your graph suggests that orbital period is **not** proportional to orbital radius?

[1]

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Johannes Kepler was a German astronomer and mathematician who analysed data describing the orbits of planets in the early seventeenth century. One of the laws that Kepler consequently deduced describes the relationship between orbital radius and orbital period.

Kepler suggested that the square of a planet's orbital period is directly proportional to the cube of its orbital radius.

Table 2

Object	Orbital Radius (in light-minutes)	Orbital Period (in days)	$\frac{[\text{Orbital Radius}]^3}{100}$	$\frac{[\text{Orbital Period}]^2}{100\,000}$
A	8.3	365	6	1
B	12.6	686		
C	19.6	1325		
D	23.0	1679		
E	26.0	2029		

(i) Complete the values of

$$\frac{[\text{Orbital Radius}]^3}{100}$$

in Table 2. Round each value to the nearest whole number. The first value has been calculated for you.

[2]

(j) Complete the values of

$$\frac{[\text{Orbital Period}]^2}{100\,000}$$

in Table 2. Round each value to the nearest whole number. The first value has been calculated for you.

[2]

(k) Plot a neat graph of $\frac{[\text{Orbital Period}]^2}{100\ 000}$ (on the *y* axis) against $\frac{[\text{Orbital Radius}]^3}{100}$ (on the *x* axis) using the data from Table 2. Include a point at the origin and draw a line of best fit. There is no need to include any units in your axis labels.

[5]

(l) Jupiter has an orbital radius of 780 million km. Using the gradient of your graph, or otherwise, determine the orbital period of Jupiter in days.

[5]

(m) A number of the objects in Table 1 are **not** planets. Explain how this may be deduced.

[3]

Earth has a surface gravitational field strength (GFS) of 10 N/kg; each kilogram of mass has a weight of 10 newtons at the surface of the Earth.

The surface GFS of a planet can be calculated using the equation

$$\text{GFS} = \frac{10 \times M}{R^2}$$

M is the mass of the planet in units where Earth's mass is 1 unit.
R is the radius of the planet in units where Earth's radius is 1 unit.

(n) Jupiter's mass is equal to 320 Earth masses and its radius equal to 11 Earth radii. Calculate the surface GFS on Jupiter.

[2]

(o) What would the surface GFS be for a hypothetical planet with the same mass as Earth but twice the volume?

[2]

(p) What would the surface GFS be for a hypothetical planet with the same density as Earth but only half the mass?

[3]

[End of Section 2 (Data Analysis)]