Name ……

RADLEY

Academic Scholarship 2018

PHYSICS

Time allowed – 90 minutes for all three science papers

Calculators are not to be used

Total marks available = 33

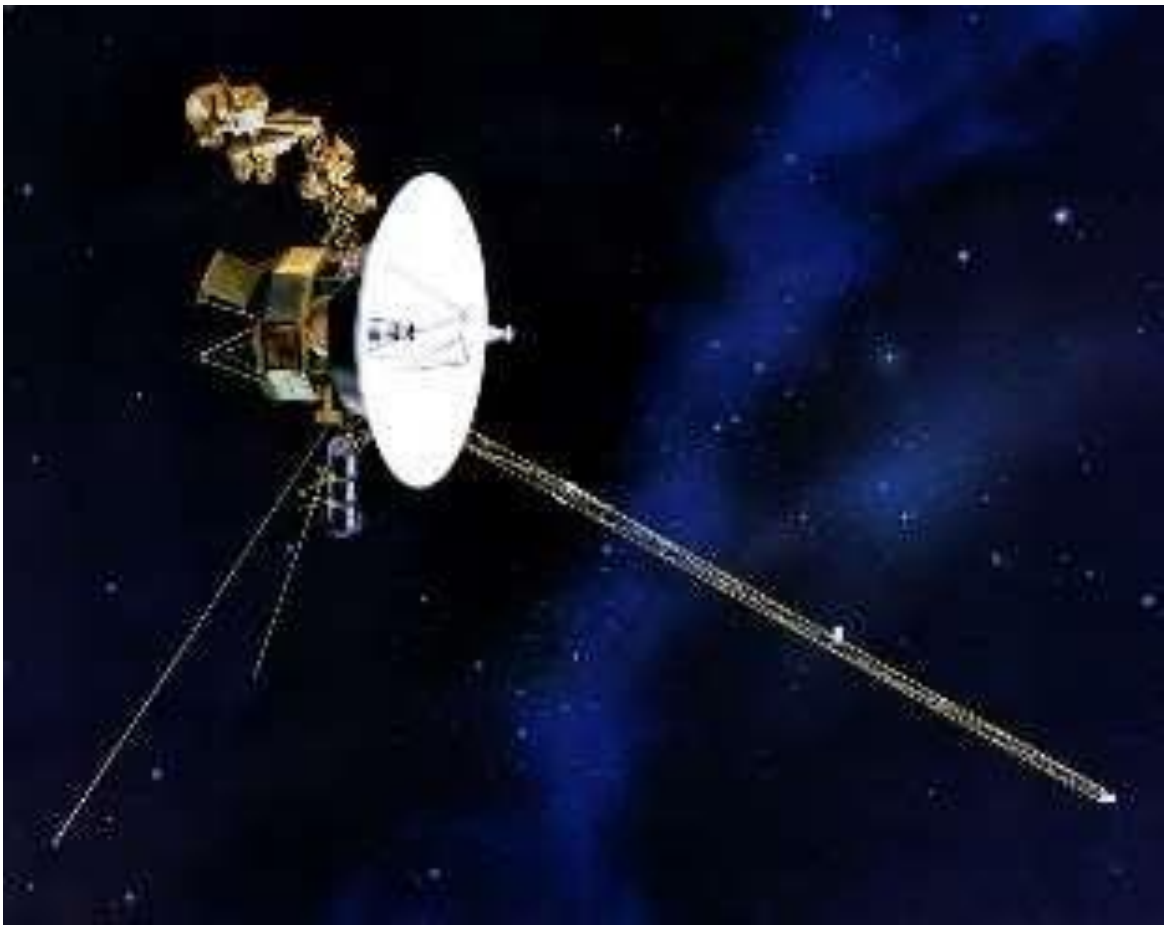
Most of the marks in these questions are for showing how well you think. Your final answers are less important than demonstrating a logical and systematic approach.

You must show your working out at all stages and state any assumptions that you make.

Where you can, use powers of ten to show very big or very small numbers. For example "1,000,000" can be written: 1.0×10^6

THE VOYAGER 1 SPACE PROBE

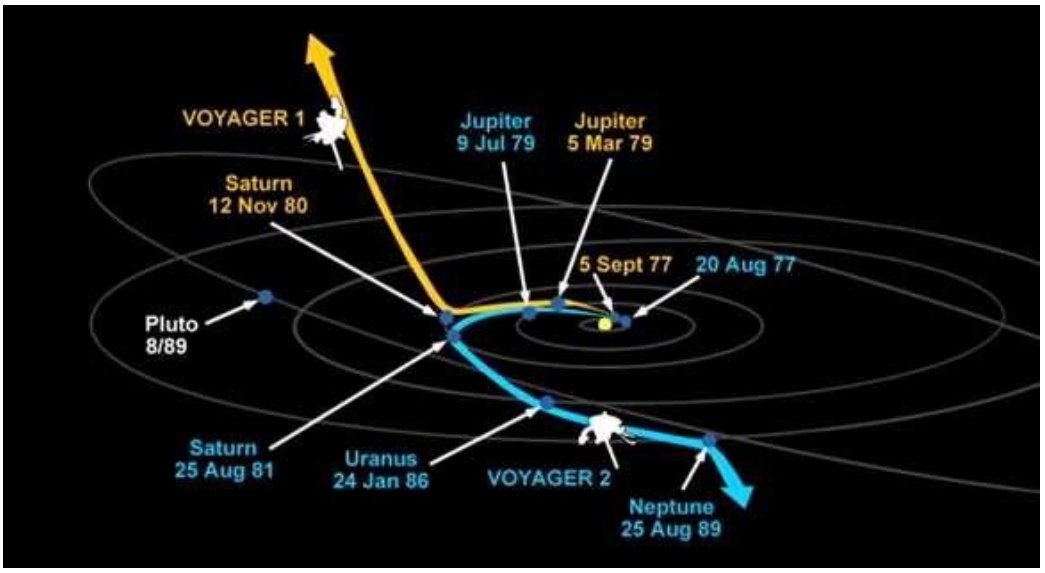
This exam is inspired by the Voyager 1 Space Probe, which celebrated its 40th birthday last year.



The probe was launched in September 1977. Its original mission was to study the outer planets, Jupiter and Saturn, and their moons; it was expected to "live" for only five years.

It has been travelling ever since, and continues to send information back to Earth from beyond our Solar System.

The Journey



1. Approximately how old will Voyager 1 be on 5th March 2018?

Express your answer in:

a) Months (to the nearest 100) [1]

b) Seconds [2]

You may make sensible approximations to simplify the numbers – e.g. you may assume that all months have 30 days.

2. Light takes 70, 000 seconds to reach Voyager 1 from Earth. What is the distance between Voyager 1 and Earth? Express your answer in metres.

As you may know, the speed of light is 3.0×10^8 m/s. [3]

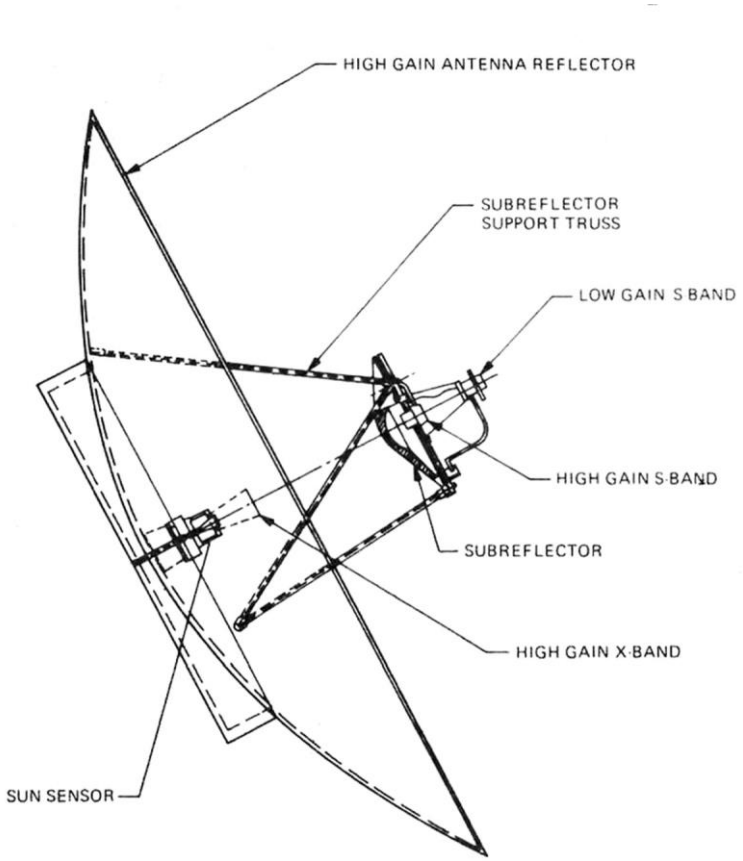
3. Your answer to Question 2 is the current distance between Voyager 1 and Earth. The total distance travelled by Voyager 1 since its launch is a little greater.

Referring to the diagram at the top of this page, explain why. [3]

4. Using your answers to Questions 1 & 2, calculate the average speed of Voyager 1 since its launch. Express your answer in metres per second. [3]

Communication

Voyager 1 includes a 3.7m diameter antenna with which to communicate with Earth, via radio waves.



5. Frequency, wavelength and speed are three important properties of radio waves. They are related by the following equation:

Wavelength (in metres) = Wave Speed (in metres per second) ÷ Frequency (in Hertz)

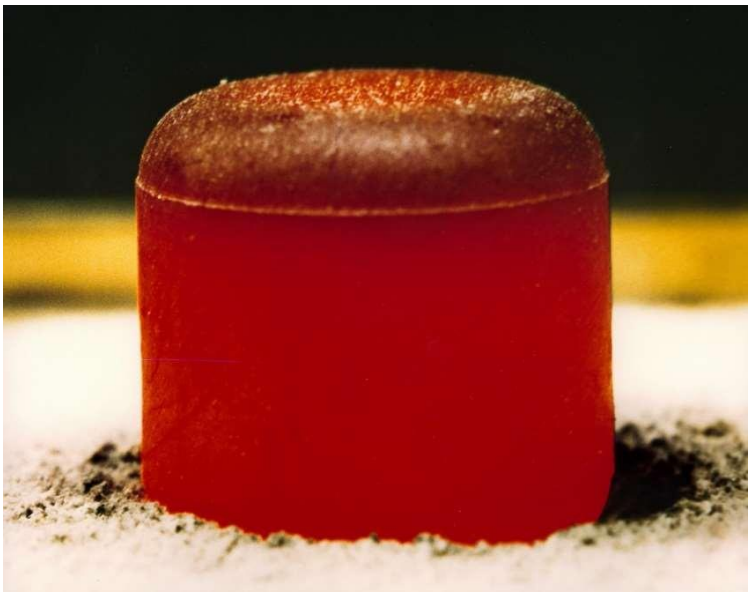
Radio wave signals from Earth to Voyager 1 are broadcast at a frequency of 2.0×10^9 Hertz.

Radio waves travel at 3.0×10^8 m/s.

Calculate the wavelength of the radio wave signals that travel from Earth to Voyager 1 – express your answer in metres [4]

Electrical Power

The scientific instruments on board Voyager 1 are powered by three thermoelectric generators, containing hot pellets of radioactive Plutonium-238.



6. When the probe was launched in 1977, the combined power output of the three generators was 500 Watts. By 2015, this had dropped to 300 Watts.

a) In 2015, by how much, in Watts, had the power output reduced? [1]

b) Express this reduction as a fraction of the original value. [2]

7. 2 grams of Plutonium-238 produces 1 Watt of power.

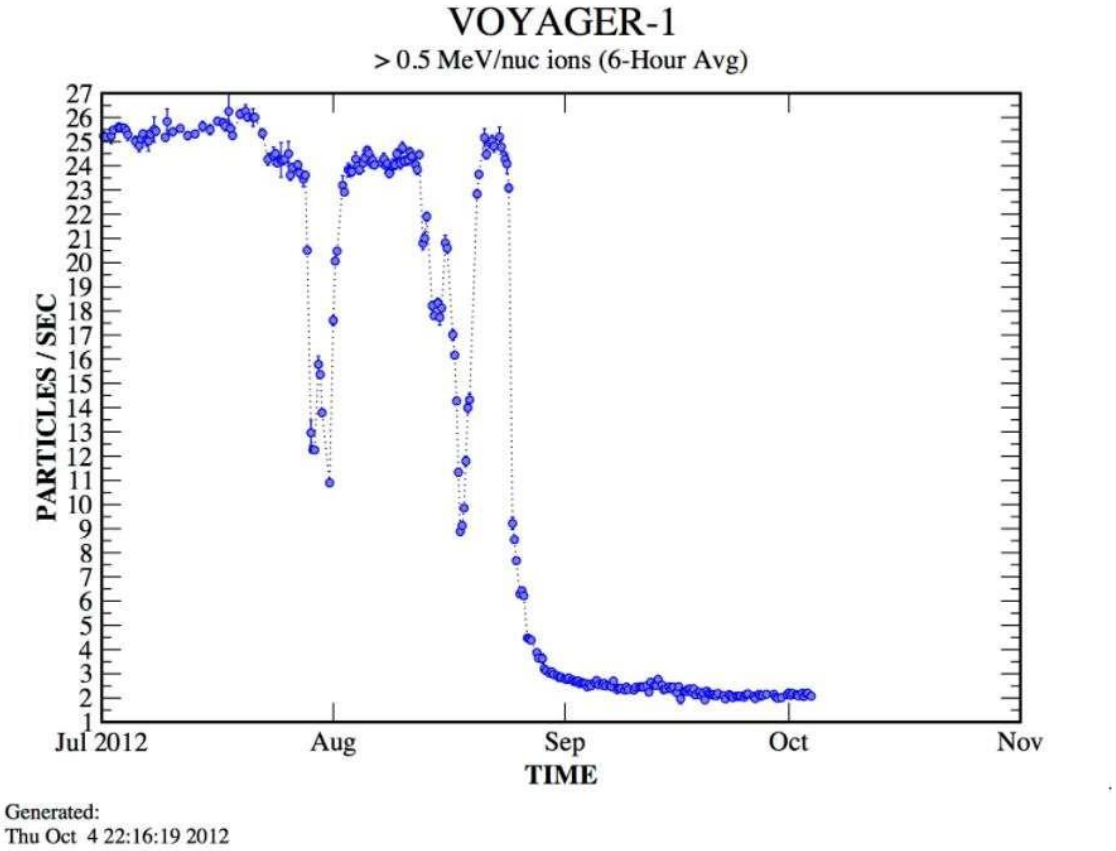
Using the information in Question 6, what was the total mass, in kilograms, of Plutonium-238 on board Voyager 1 when it launched? [2]

8. "Half-life" is the time taken for the power output of a radioactive substance to halve. The half-life of Plutonium-238 is 87.5 years.

How long would it take for the power output of a sample of Plutonium-238 to reduce to 25% of its initial value? [2]

Reaching the Interstellar Medium

In 2012, data from the on-board particle detector provided evidence that the probe had entered interstellar space (a region beyond the reach of charged particles originating from within our Solar System).



9. By considering the above graph, suggest an approximate date upon which Voyager 1 reached interstellar space. Explain your answer. [2]

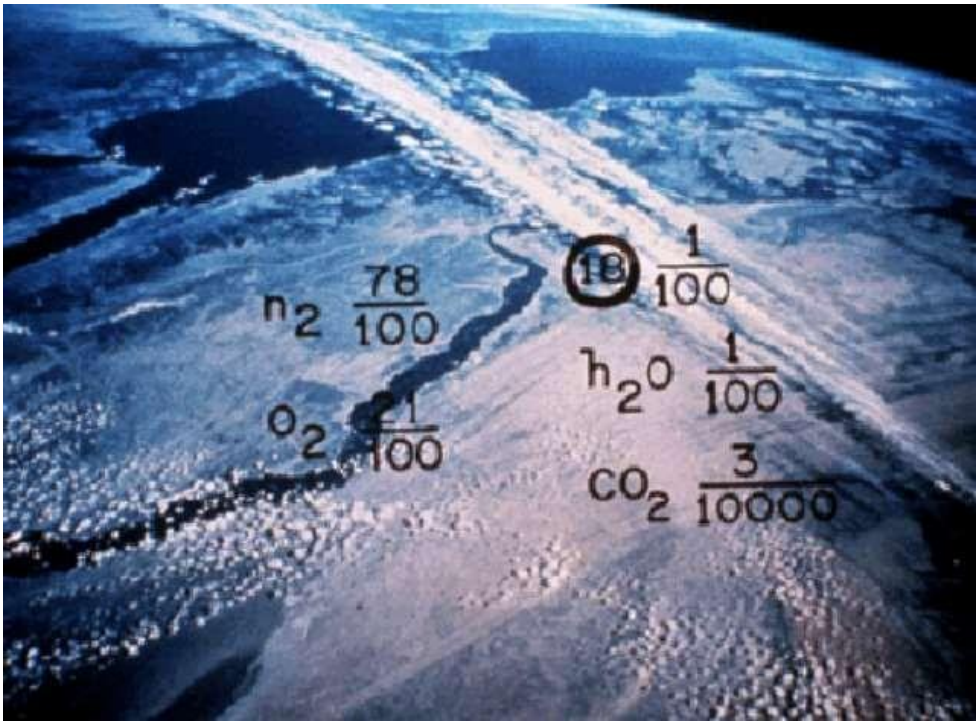
The Golden Disc

Voyager 1 carries a time capsule in the form of a gold-plated copper record. It contains images, music and sounds that represent life on Earth: the shriek of a chimpanzee, an excerpt from Stravinsky's Rite of Spring, a photo of a fat man eating a donut, and much more...

10. The record includes the following picture of Jupiter, indicating its diameter. Can you suggest an explanation for "318 e"? [2]

11. Also included is the following photograph of the River Nile.

Can you suggest an explanation for the annotations? [3]



12. What three things would you have included on the Golden Disc?

Briefly explain your choices. [3]