Advanced level GCE Physics B

Unit G494 Rise and Fall of the Clockwork Universe – High banded Candidate style answer

Introduction

OCR has produced these candidate style answers to support teachers in interpreting the assessment criteria for the new GCE specifications and to bridge the gap between new specification release and availability of exemplar candidate work.

This content has been produced by senior OCR Examiner's, with the input of Chairs of Examiner's, to illustrate how the sample assessment questions might be answered and provide some commentary on what factors contribute to an overall grading. The candidate style answers are not written in a way that is intended to replicate student work but to demonstrate what a "good" or "excellent" response might include, supported by examiner commentary and conclusions.

As these responses have not been through full moderation and do not replicate student work, they have not been graded and are instead, banded "medium" or "high" to give an indication of the level of each response.

Please note that this resource is provided for advice and guidance only and does not in any way constitute an indication of grade boundaries or endorsed answers.

Section A

1 Fig 1.1 shows three possible paths, <u>A, B</u> and <u>C</u>, of a spacecraft moving near the Earth, but well above the atmosphere.

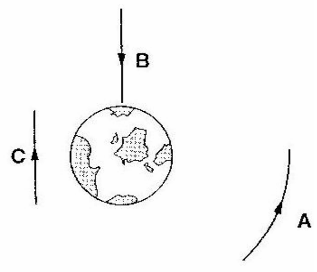


Fig. 1.1

(a) Which path follows a gravitational field line of the Earth?

[1]

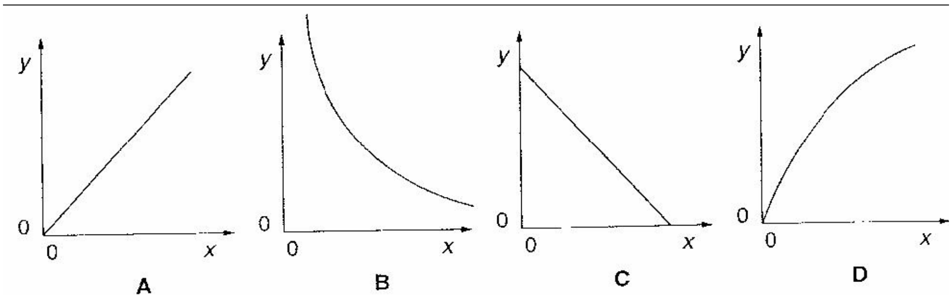
Candidate style answer	*Examiner's commentary*
B	This question is typical of an opening question to help the candidates begin the examination. It relies on recall of representations of the gravitational field. The most common error is to get the field line/equipotential line the wrong way round.

(b) Which path follows a gravitational equipotential line of the Earth?

[1]

Candidate style answer	Examiner's commentary
A	

2 Study the graphs A, B, C, D



(a) Which graph shows the variation in volume (*y*) of a fixed mass of gas at constant pressure with absolute temperature (*x*)?

[1]

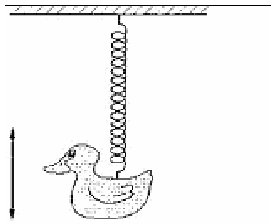
Candidate style answer	Examiner's commentary
A	This is another recall question that a good candidate should be able to manage with ease.

(b) Which graph shows the variation in pressure (*y*) of a fixed mass of ideal gas at constant temperature with volume (*x*)?

[1]

Candidate style answer	Examiner's commentary
B	Correct answer.

3 A plastic duck hangs from a long spring. The duck oscillates vertically with a frequency of 0.42 Hz.



The displacement *x* of the duck at time *t* is given by the equation

$x = A \cos(2 \pi f t)$

where A = 0.20 m.

Choose the value from the list below which gives the displacement of the duck when *t* = 2.0 s.

0.11 m   0.20 m   -0.11 m   -0.20 m

[1]

Candidate style answer	Examiner's commentary
chosen value = *0.11 m*	The student identified the correct answer. This may have been luck, but the expected method is: x = 0.20 cos(2 π x 0.42x2.0) = 0.20 cos 5.28

	= 0.20 x 0.54 = 0.108 m It is perhaps worth stressing that silly errors can be avoided by setting out the calculation in easy stages.

4 2.0 mol of an ideal gas is kept at a pressure of 1.5 x 10^5 Pa and a temperature of 310 K.

Calculate the volume occupied by the gas under these conditions.

***R* = 8.3 J K^{-1} mol^{-1}**

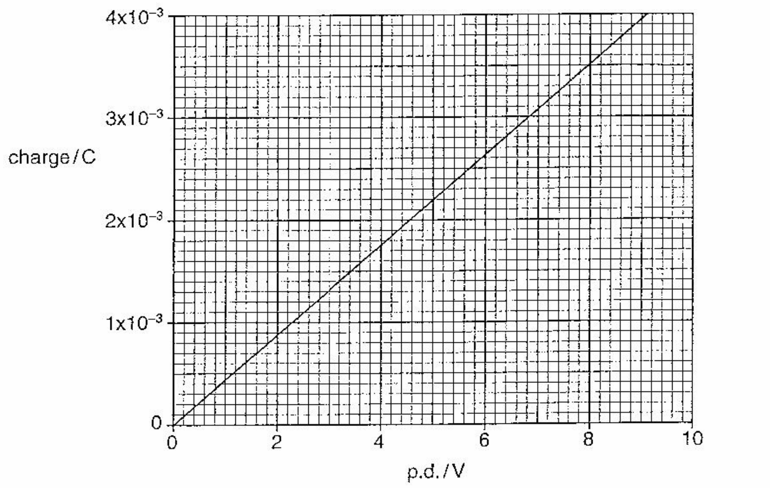
pV = nRT ∴ V = nRT/p = 2 x 8/3 x 310/1.5 x 10^5

V = 3.4 x 10^{-2} m^3

[2]

Candidate style answer	*Examiner's commentary*
volume = 3.4 x 10^{-2} m^3	Note that this calculation is worth two marks. As the first mark is awarded for a correct method it is worthwhile to ensure that candidates do include all stages in such calculations. Merely writing down the correct answer would gain both marks but this candidate sensibly includes all working.

5 The graph shows how the charge on a capacitor varies with p.d. across the capacitor.



Here are a number of values:

440 210 350 700

Use information from the graph to choose from the list the best value for

(a) the capacitance of the capacitor in microfarad

[1]

Candidate style answer	*Examiner's commentary*
value = 440 μF	

(b) the energy in μJ stored on the capacitor when a p.d. of 4.0 V is applied across it.

[1]

Candidate style answer	*Examiner's commentary*
value = 350 μJ	Two more correct answers. Notice that this question requires careful reading of data from a graph. Candidates are inclined to rush these questions and make unnecessary errors through poor reading of scales and points.

6 A circus clown fires a water gun that ejects water horizontally at a speed of 7.3 m s^{-1}. The water leaves the gun at a rate of 2.7 kg s^{-1}.

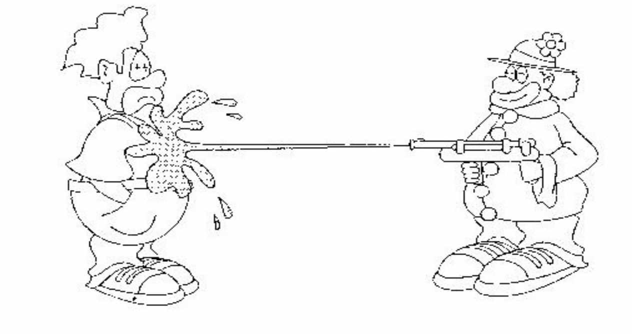


Fig. 6.1

Explain why the clown holding the gun experiences a backward force of about 20 N.

The force on the water is 2.7 x 7.3 = 19.7 N

[3]

Candidate style answer	*Examiner's commentary*
The change of momentum of the water per second, rate of change of momentum, is 2.7 x 7.3 = 19.7 kg m s^{-1} Rate of change of momentum is the force on the water. From Newton's third law the clown will experience an equal and opposite force pushing against him.	This candidate scored full marks here. There was a clear link from a correctly calculated rate of change of momentum to the force on the water, and a clear clink to the force on the clown. Notice that it is quite easy for even a high scoring candidate to lose marks through missing stages in an argument.

7 Fig 7.1 shows a circuit diagram of a capacitor discharging through a resistor.

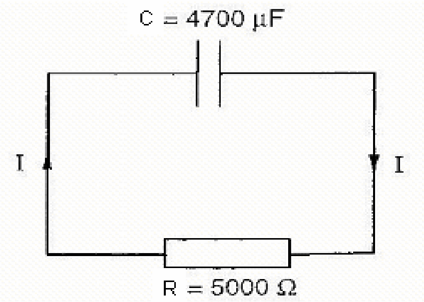


Fig. 7.1

A simple mathematical model of the discharge of the capacitor is shown in Fig. 7.2. It is assumed that the current *I* is constant over each small time interval Δ*t*. This process is repeated as shown.

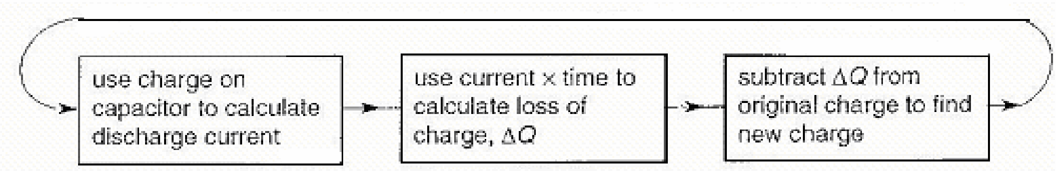


Fig. 7.2

(a) Complete the table for the discharge of the 4700 μF capacitor. The small time interval used is Δ*t* = 2.0 s.

Q	$I = \frac{V}{R} = \frac{Q}{RC}$	$\Delta Q = I\Delta t$	$Q_{new} = Q - \Delta Q$
5.64×10^{-2} C			5.16×10^{-2} C
5.16×10^{-2} C			

[2]

Candidate style answer	*Examiner's commentary*
Line 1: 2.4×10^{-3} , 4.8×10^{-3} **Line 2:** 2.2×10^{-3} , 4.4×10^{-3} , 4.7×10^{-2}	The candidate gained all the marks available for this question.

(b) **Suggest one reason why mathematical models are useful in physics.** **[1]** **[Section A Total: 15]**	
Candidate style answer	*Examiner's commentary*
`It can help to predict outcomes when you can't do the actual experiment, for example, you might not have a capacitor of that size.  Some theories can only be formulated as mathematical models.`	The mark in section b was gained in the first sentence.

General Comments on Section A: This candidate gained a high proportion of the marks available. This is not unusual for able and well prepared candidates.

Section B:

8 This question is about the time it takes a planet to orbit once around the Sun. This is called the orbital period of the planet.
In this question, the following symbols will be used:
orbital period *T*
mean radius of orbit *R*
mass of Sun *M*s
mass of planet *M*p

(a) The seventeenth century astronomer Johannes Kepler (Fig. 8.1) suggested a relationship between the orbital period of a planet *T* and its radius of orbit *R*.
This relationship can be written as

$$T^2 \alpha R^3$$

Kepler found this mathematical relationship by trial and error.

Data for four of the planets are shown in Fig. 8.2.

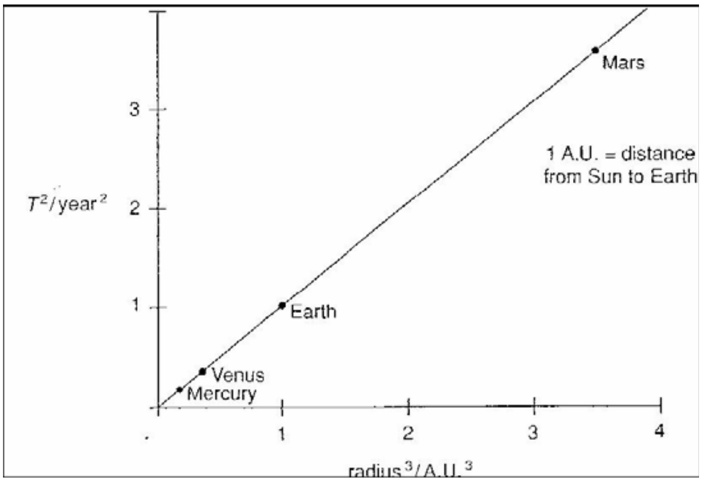


Fig. 8.2

State which features of the graph show that T^2 is proportional to R^3.

[2]

Candidate style answer	*Examiner's commentary*
`The graph is a straight line through the origin.`	Candidates tend to find questions about gravity quite difficult. However, this candidate produced superb answers to all but part d where the answer was not awarded a mark. Part (a) is an easy starter.

(b) Isaac Newton (Fig. 8.3) developed a description of gravity that confirmed Kepler.s work. Newton.s confirmation of Kepler was based on his laws of motion and his gravitational law..

The centripetal force on a planet of mass M_p orbiting with period *T* at radius *R* is given by

$$F = - M_p (2\pi)^2 / T^2 R$$

Use Newton's Gravitational Law F = - GM_pM_s/R^2 to show that $T^2/R^3 = (2\pi)^2/GM_s$ and hence find the mass of the Sun.

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

Mean radius of Earth's orbit = 1.5 x 1011 m-

Mp (2π)2 R / T2 = - GMpMs/R2

(2π)2 = T2 GMs/R3

(2π)2/ GMs = T2/R3

Ms = (2π)2 R3/ T2G

[4]

Candidate style answer	*Examiner's commentary*

`= (2π)2 x (1.5 x 1011)3/(3.2 x 107)2x 6.7 x 10-11`
 	
`= 1.8 x 1030 kg`
 	
mass of Sun = `1.8 x 1030 kg`
	Part (b) was well attempted; the candidate gave concise reasoning, ensuring that the examiner could follow stages in the argument. High scoring candidates rarely make errors in calculations, but it was encouraging that all working was shown. However, the candidate made an arithmetic error at the end of the question which dropped a mark. Notice that by including all working the candidate gained most of the marks available - had the working been less clear more marks would have been lost.

(c) The Sun loses mass at a rate of 6.2×10^{11} kg s^{-1}. Discuss whether this will have had any significant effect on the orbit the Earth over the 40 000 years that humans have made an impact on the planet.

! You will be awarded marks for the quality of your written communication.

[3]

Candidate style answer	*Examiner's commentary*
Over forty thousand years the Sun will have lost about 8×10^{23} kg. This is only about 4×10^{-5} % of the mass of the Sun so will have little effect on the orbit of the Earth as the field strength at the Earth will alter in proportion. This fits in with the lack of evidence of oribital change in history and archaeology.	Part (c) shows what a good candidate can do. Once again, all steps were included in a clear, logical explanation. The last sentence appears to be an attempt to prove a negative and did not contribute to the mark on the question.

(d) Although Kepler's findings were hugely important, Newton's are considered to be more significant.

Give <u>one</u> reason why Newton's approach is considered an advance on Kepler's approach.

[1]
[Total: 10]

Candidate style answer	Examiner's commentary
Newton's was more mathematical.	Part (d) was surprising – the response was a rather empty statement that does not really get to the heart of the question.

9 This question is about heating soup with microwaves.

(a) The microwave oven supplies energy to the soup at a rate of 600 W.

The soup, of mass 0.40 kg, has an initial temperature of 20 ^{o} C.
Show that, after three minutes, the maximum temperature will be about 85 ^{o} C.

specific thermal capacity of soup = 4200 J kg^{-1} K^{-1}

[2]

Candidate style answer	Examiner's commentary
energy supplied = m c $\Delta\theta$ $\Delta\theta$ = 600 x 180/(0.4 x 4200) = 64.3° C 20 + 64.3 = 84.3 which is about 85 ° C.	The candidate gained most of the marks for this question. Part (a) gained some marks and showed a clear, concise method.

(b) The Boltzmann factor is given as $f = e^{-E/kT}$. Describe what the Boltzmann factor indicates and use it to explain why increasing numbers of molecules evaporate from the soup as its temperature rises.

! You will be awarded marks for the quality of your written communication.

[4]

Candidate style answer	Examiner's commentary
The Boltzmann factor shows the proportion of particles with enough energy to evaporate at a given temperature. Increasing the temperature decreases –E/kT, making it less negative. Raising e to a smaller negative number gives a bigger Boltzmann factor which shows that a bigger proportion of the particles will have the required energy.	Part (b) was like a model answer. All the points required were covered with clarity and the candidate gained the QWC mark through precise use of language. The candidate had clearly prepared this part of the course thoroughly.

(c) The soup container has a tight fitting lid on it.

As the temperature rises:

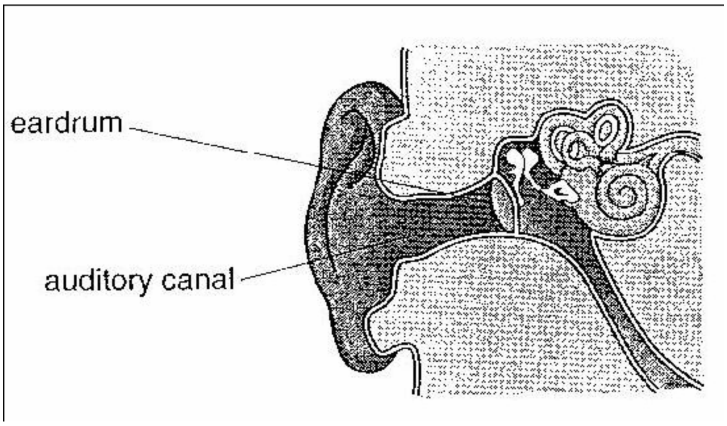
the number of molecules in the vapour increases

the average speed of the molecules in the vapour increases.

Use ideas about momentum to explain why the growing number of molecules in the vapour and the increase in average speed of the molecules both increase the pressure of

the vapour. [4] [Total: 10]	
Candidate style answer	*Examiner's commentary*
`Particles hitting the lid experience a change of momentum. As force is rate of change of momentum the particles (and the lid) experience a force as I described in the question about clowns.. As pressure is F/A there will be a pressure on the lid. Increasing the number of particles will increase the pressure as there will be a greater rate of change of momentum – more particles hit the lid. The same for temperature.`	Part (c) gained the candidate most of the marks available. The last sentence was not clear enough to gain a mark. The rather facetious reference to a previous question was ignored by the examiner.

10 This question is about some of the physics of the human ear.



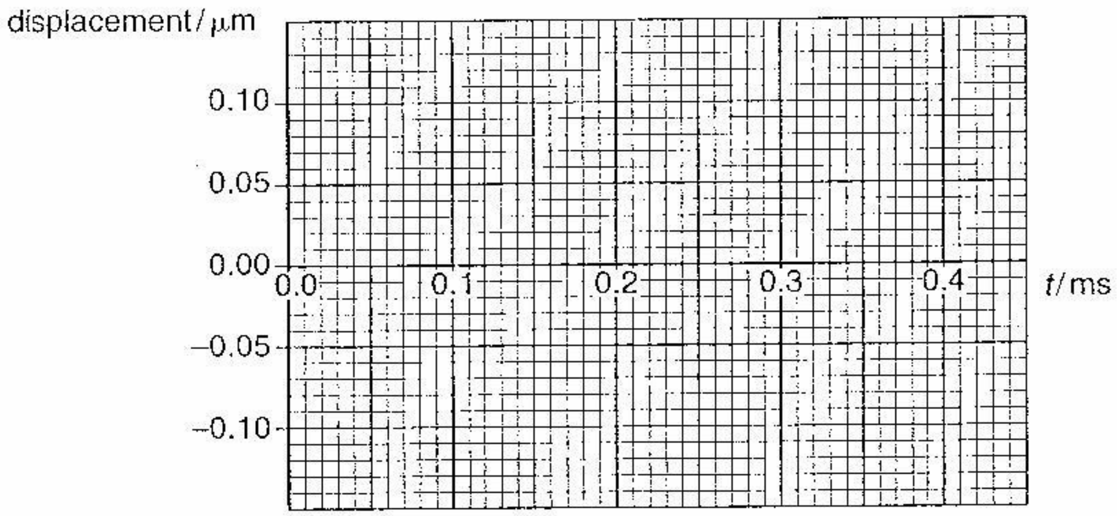
A given sound wave striking the ear drum sets it oscillating in simple harmonic motion. The ear drum oscillates at a frequency of 2500 Hz with an amplitude of 1.0×10^{-7} m.

(a) (i) Calculate the period of the oscillation.

[1]

Candidate style answer	*Examiner's commentary*
`Period = 1/frequency = 0.0004` `period = ` ***0.0004*** `s`	

(ii) On the axes of Fig. 10.2, draw a graph to show how the displacement of the eardrum varies with time for one oscillation. Assume that the displacement is zero at t = 0.



Candidate draws correct sinusoidal curve with period of 0.4 ms and amplitude 0.1 μm.

(iii) Calculate the maximum acceleration of the ear drum.

[2]

Candidate style answer	*Examiner's commentary*
$a = -4\pi f^2 A = -4\pi f^2 \times 1 \times 10^{-7} = -24.7$ m s^{-2} **acceleration =** -24.7 m s^{-2}	

(iv) Mark on the graph on Fig.10.2 a point at which this maximum acceleration occurs. Mark this point a.

[1]

Candidate style answer	*Examiner's commentary*
	Candidate correctly marks a point where the displacement is a maximum.

(b) The resonant frequency of the human auditory canal is around 3000 Hz, which makes the human ear most sensitive at those frequencies.

Explain clearly what this statement means, and suggest circumstances in which lower or higher resonant frequencies might be expected in humans or other mammals.

! You will be awarded marks for the quality of your written communication.

[5]

[Total: 12]

Candidate style answer	*Examiner's commentary*
Resonance happens when the frequency of the thing making the oscillator move is the same as the natural frequency of the oscillator. In this case the frequency of the vibration of the air matches the frequency of the	The candidate was awarded most of the marks for this question.. Part (b) was well answered and gained the QWC mark but the candidate did not link a different resonance frequency with a consequence such as being more sensitive to

ear drum. When this happens the amplitude of the ear drum is larger. A longer auditory canal would make the resonance frequency lower.	lower frequencies.

11 This question is about calculating the age of stars using the radioactive decay of uranium-238.

(a) A sample containing 1.0×10^{-6} kg of uranium-238 contains 2.5×10^{18} uranium-238 atoms.

The activity of the sample is 12 Bq.

Show that the half-life of uranium-238 is about 4.5 billion years.

1 year = 3.2×10^{7} s

decay constant = $12/2.5 \times 10^{18} = 4.8 \times 10^{-18}$

Half life = $\ln 2/\lambda = 0.693/4.8 \times 10^{-18} = 1.44 \times 10^{17}$ s

[3]

Candidate style answer	*Examiner's commentary*
$= 1.44 \times 10^{17}/3.2 \times 10^{7} = 4.5 \times 10^{9}$ years	The candidate gained high marks here. Part (a) was clearly answered and it is always good to see candidates giving final answers on the answer line.

(b) A small sample of rock contains 10 atoms of uranium-238. Estimate, <u>without calculation</u>, the number of atoms of uranium-238 that would have been present in that rock at the time when the Solar System is believed to have formed, 5.6 billion years ago, and explain how you obtained that estimate.

Explain clearly why a precise calculation would not have given an accurate answer of the number originally present.

[4]

Candidate style answer	*Examiner's commentary*
5.6 billion years is a bit more than one half life. If one half life had passed we would expect about twice as many atoms of uranium-238 to be present at the beginning, about 20 atoms. So perhaps there were 23 atoms of uranium-238 at the start. This isn't accurate because radioactive decay is random and there were very few atoms to begin with.	Part (b) was also clearly answered. The candidate lost a mark because the need for large numbers of nuclei in the sample for confident dating was not made particularly clear. The rest of the question was a model of clarity.

(c) Astronomers have observed the spectrum of a very old nearby star to determine how much uranium-238 it contains. This value is compared with the amount that is thought to have been present when the star was formed.

Recent observations suggest that the amount of uranium-238 in the star has fallen to 12 % of its original value.

Calculate the age of the star in years.

ln0.12 = (-4.8 x 10^{-18})t ***t = 2.12/(4.8 x 10^{-18}) = 4.4 x 10^{17} s = 1.4 x 10^{10}*** **[2]**

Candidate style answer	Examiner's commentary
`age of star =` *1.4 x 10^{10}* `years`	Correct answer. `

(d) The Hubble Law, based on observation of cosmological red shifts, suggests that the universe is much older than the age of the stars measured by finding how much uranium-238 it contains. **Explain the meaning of the term cosmological red shift.** **[1]**

Candidate style answer	Examiner's commentary
`Space is expanding. This expansion stretches the wavelength of light traveling through it.`	Correct answer.

(e) The Hubble Law suggests that the age of the universe is of the order 1/H_0 where H_0 is the Hubble parameter. Estimating the value of H_0 is an extremely important task. Values for H_0 have ranged from 1.6 x 10-18 s^{-1} to 3.2 x 10-18 s-1. **(i) Estimate the minimum and maximum age of the universe in years from the value of H_0.** **[2]**

Candidate style answer	Examiner's commentary
minimum age = *9.8 x 10^9* `years` **maximum age =** *1.8 x 10^{10}* `years`	Correct answer.

(ii) Explain how data from the uranium-238 method of finding the age of stars can be used to help astronomers choose between these values of H_0. **[1]** **[Total: 13]** **[Section B Total: 45]** **Paper Total [60]**

Candidate style answer	Examiner's commentary
`The stars must have been formed after the Big Bang so the minimum age calculated cannot be correct because it is less than the age of the stars!`	Correct answer.

Overall banding: Medium

This candidate scored high marks on the paper as a whole. The candidate displayed an extensive and solid knowledge of physics and expressed ideas with clarity at nearly all times. This paper shows very well prepared candidate.