Advanced GCE Physics B

Unit G494 Rise and Fall of the Clockwork Universe - Medium 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, A, B and C, of a spacecraft moving near the Earth, but well above the atmosphere.

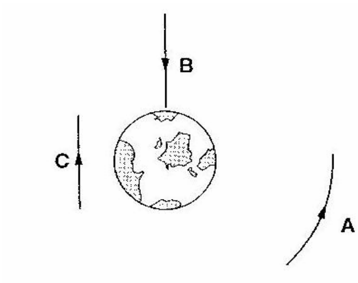


Fig. 1.1

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

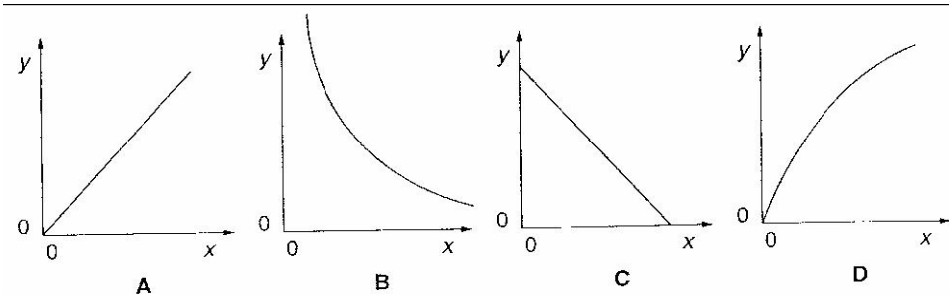
[1]

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]

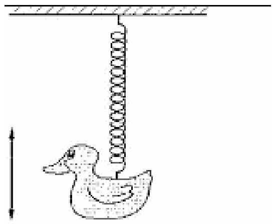
Candidate style answer	*Examiner's commentary*
A	This is another recall question that a medium or good candidate should be able to manage with ease.

(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	

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 = *0.20 m*	The answer given by the candidate is <u>incorrect</u>. Use of this equation can cause problems. At one level, the candidate may not remember to use the radian mode on the calculator or simply make an error. It would

	help candidates if they fully understood why their calculators should be switched to radian mode for such calculations. The correct calculation 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 1.5×10^5 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}**

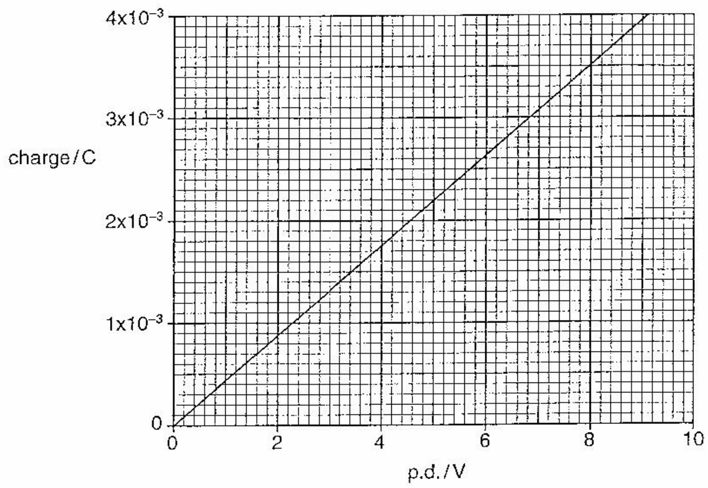
pV = nRT ∴ V = nRT/p = 2 x 8/3 x 310/1.5 x 10^5

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

[2]

Candidate style answer	*Examiner's commentary*
volume = *3.7 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. So, although the candidate made an arithmetical slip he/she was awarded one method mark.

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	The first answer, from the gradient of the graph, is correct.

(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 = *700* µJ	The second answer is <u>incorrect</u>. The correct answer is 350 µJ. The candidate probably used E = QV rather than the correct equation for energy stored on a capacitor, which is E = ½ QV. This is a common error. Notice also 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}.

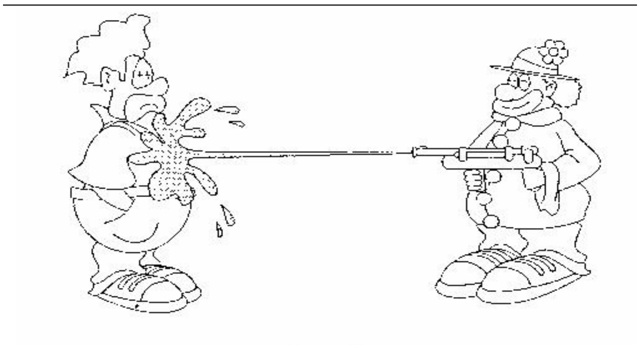


Fig. 6.1

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*
Newton's Third Law suggests that the clown will experience an equal and opposite force to that, so the clown experiences a backward force of about 20N	This candidate scored some of the marks available. The calculation of force was essentially correct but the candidate did not make it clear that the calculation gave the rate of change of momentum so the explanation was incomplete. Newton's Third Law often gives candidates problems as they use it as a general answer without putting it in the specific context of the question. This candidate gained the mark for the Newton's Third Law point because it was placed in context.

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

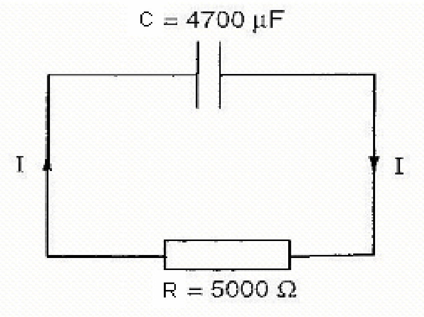


Fig. 7.1

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.

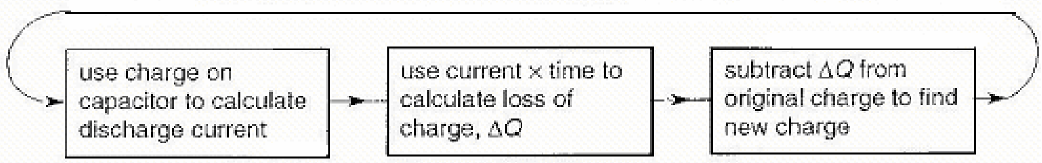


Fig. 7.2

(a) Complete the table for the discharge of the 4700 μF capacitor. The small time

interval used is Δt = 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 x 10-3 ,  4.8 x 10-3` **Line 2:** $^{2}2.2 \times 10^{-3}$, 4.4×10^{-3} , 4.7×10^{-2}	The candidate gained all the marks available for this question. Sometimes candidates can miss gaining marks in 'suggestion' questions because they do not think carefully enough about their responses. For example, the response 'you can't always do an experiment' is barely sufficient to gain the mark.

(b) Suggest one reason why mathematical models are useful in physics.

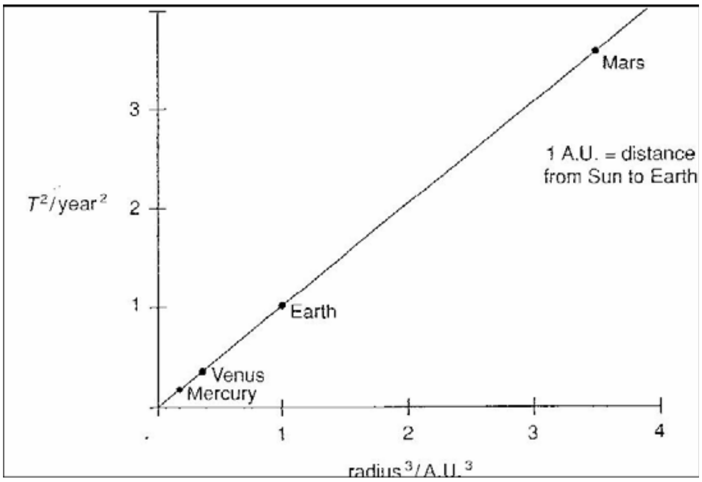
[1]

[Section A Total: 15]

Candidate style answer	*Examiner's commentary*
`It can help to predict outcomes when you can't do the actual experiment.`	

General Comments on Section A: This candidate gained some of the marks available. Those marks lost could have been avoided by reading questions a little more carefully and checking that explanations were sufficiently detailed. This is typical of the performance of a medium-ranked candidate in this paper.

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.`	Candidates tend to find questions about gravity quite difficult. This candidate dropped a proportion of the marks but this is not a bad attempt from a medium grade candidate. Part (a) should have been easy but the candidate dropped a mark for not stating that proportionality is shown by a straight line through the origin of the graph.

(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 1027 kg	Part (b) was well attempted, perhaps not the most elegant of proofs but successful. However, the candidate made an arithmetic error at the end of the question which lost marks. Notice that by including all working the candidate gained marks - 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 a very small proportion of the mass of the Sun so will have little effect on the orbit of the Earth.	Part (c) shows the need to be as clear as possible in explanation questions. The candidate covered the basic points but was only awarded two marks because the explanation was not as clear as it could be. The proportion of the mass of the Sun lost could have been shown and the difference this makes to the gravitational field of the Sun at the Earth's orbit could have been calculated. However, it was encouraging to see the calculation of the mass lost over the time period given. Candidates should be encouraged to use data given whenever possible. Weaker candidates just assumed

	that the rate of loss of mass must have had effects on the Earth, even though none had been recorded.

(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 worked his ideas out from first principles Kepler just did trial and error.`	Part (d) was answered in a rather rushed fashion by this candidate who wrote just enough to be given the mark. What did the candidate mean by 'first principles'? Giving a fuller response is more advisable to ensure that the answer hits the marking points.

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*

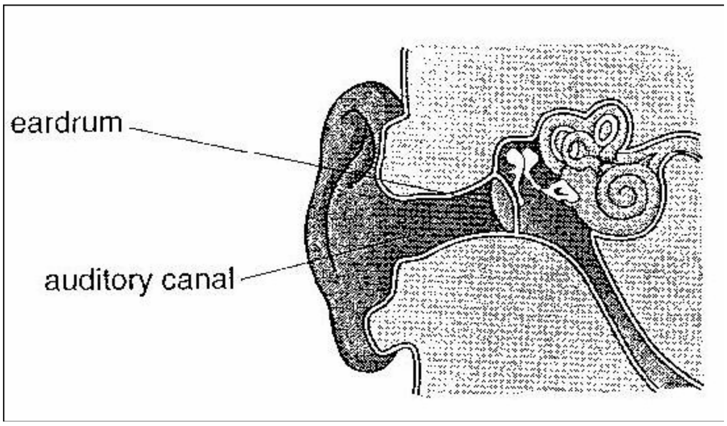
`Temp change = 65°C`
`Energy required = 0.4 x 4200 x 65 = 109200`
`Time to supply this energy = 109200/600 = 182 s`
`This is nearly 180 s which is three minutes`
	The candidate gained few of the marks for this question, although probably thought that the score was higher! You can see that the answers are a little rushed and tend to gloss over points of physics – this reduces the marks awarded.
	
	Part (a) gained some marks although the method used is not the one expected. In 'show that' questions such as this it is more usual to work from the data through to the answer and then compare it with the value given. However, some medium-grade candidates work backwards from the answer given to show that the data is consistent.

(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*
`Shows how many particles will have enough energy to evaporate. When T gets bigger the factor increases so more particles evaporate.`	Part (b) scored no marks, due in some part to poor use of language. The candidate wrote that the Boltzmann factor '*Shows how many particles will have enough energy to evaporate*' . This is not the case – it shows the proportion

	of particles with sufficient energy to evaporate, not the number. The candidate missed out on a mark linking Boltzmann factor to temperature because it was not made clear how temperature affects *f*; bald statements are not explanations at A2 level. The brevity of the response and the lack of technical vocabulary stopped the award of a QWC mark.

(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*
`When particles hit the lid they have a change of momentum, this pushes the lid because force is rate of change of momentum. More molecules hitting the lid will increase the force because their is more momentum change. Also faster molecules hit the walls harder so they have more momentum.`	Part (c) gained the candidate some marks although the language used was imprecise and the spelling left much to be desired. Although there was sufficient understanding shown to match the requirements of the mark scheme the candidate should be encouraged to set out arguments more precisely. It is more logical to lay out any definitions at the beginning of an argument, in this case that force is equal to rate of change of momentum, and then apply the definition to the specific situation in the question. The candidate missed a mark through failing to link pressure increase to increasing force over a fixed area.

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



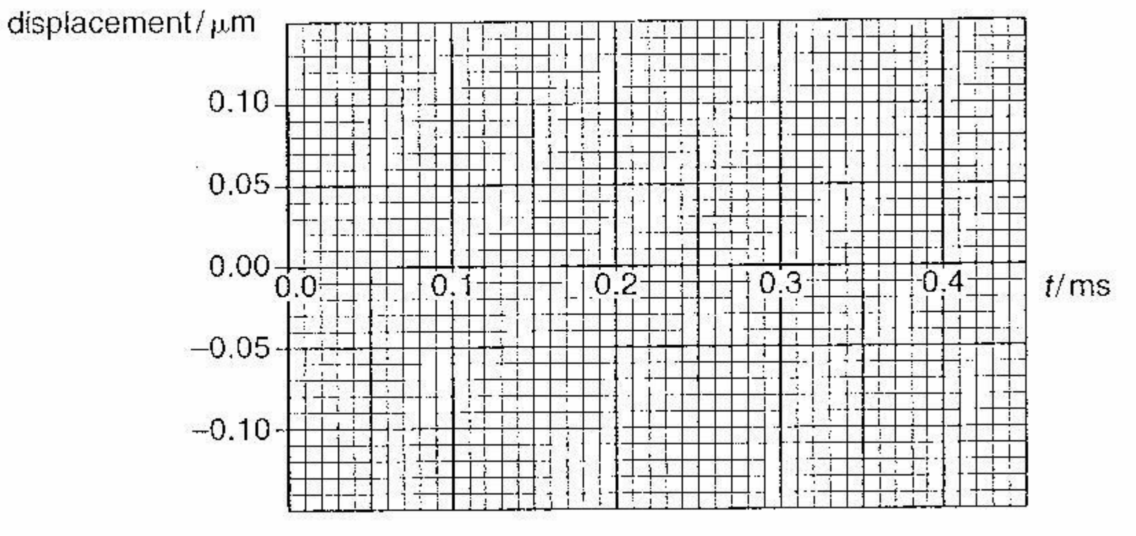
A given sound wave striking the ear drum sets it oscillating in simple harmonic motion. The ear drum oscillates at a frequency of 2500 Hz with an amplitude of 1.0×10^{-7} m.

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

[1]

Candidate style answer	*Examiner's commentary*
`Period = 1/frequency = 0.0004` `period =` ***0.0004*** `s`	Parts a (i), a (ii) and a (iii) were all answered correctly.

(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*
$a = -4\pi f^2 A = \ x\ 1 \times 10^{-7} = 24.7\ m\ s^{-2}$ **acceleration =** m s^{-1}	Parts a (i), a (ii) and a (iii) were all answered correctly.

(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 incorrectly marks a point where the line crosses the x-axis.`	The candidate made a silly error on part a(iv) which contradicted the answer calculated in a(iii). This kind of unthinking error is not uncommon; it is another example of not taking a moment to consider exactly what the question is asking.

(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*
`The ear drum will vibrate most at this 3000 Hz because it resonates. A bigger ear might give a different resonant point because there is more air in the ear. With more air the resonant point would be lower. So big animals might have lower resonance than small animals. That's why bats use echo location.`	Part (b) was a little more tricky for the candidate. The answer was poorly laid out and although the marker may have thought that the candidate probably knew more than was written, there was not enough evidence to award marks. The answer should start with defining terms – in this case 'resonance'. The second point would be to say that the oscillation of the ear drum would reach a higher amplitude at resonance. The candidate merely said it would 'vibrate most', this statement is too vague. Similarly, the candidate did not really talk about the length of the auditory canal but wrote of 'more air' – this is not incorrect but it is insufficient evidence of understanding to gain a mark. A mark was awarded for the link between more air and resonant frequency. The point about echo location was nothing to do with the question and the candidate did not show sufficient organization of the answer to gain the QWC mark.

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

(a) A sample containing 1.0 x 10^{-6} kg of uranium-238 contains 2.5 x 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 x 10^{7} s

decay constant = 12/2.5 x 10^{18} = 4.8 x 10^{-18}

Half life = ln2/λ = 0.693/4.8 x 10^{-18} = 1.44 x 10^{17} s

[3]

Candidate style answer	*Examiner's commentary*
= 1.44 x 10^{17}/3.2 x 10^{7} = 4500000000 years	Part (a) was reasonably clearly answered, although writing out a string of zeroes rather than using standard notation is not very clear and leaves more room for error. Candidates should use standard notation where possible.

(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
I reckon that there where about 22 present when the system was formed. This is because about a half-life has past. It is only an estimate because I didn’t calculate it properly and radioactive decay is random.	Part (b) was not clearly answered although most of the major points were met. The candidate did not explain why the random nature of radioactive decay is important in this situation (few radionuclei present). The candidate clearly knew how to perform radioactivity calculations and had a good understanding of cosmological redshift.

(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 = $(-4.8 \times 10^{-18})t$

$t = 2.12/(4.8 \times 10^{-18}) = 4.4 \times 10^{17}$ s $= 1.4 \times 10^{10}$

[2]

Candidate style answer	Examiner’s commentary
age of star = 1.4×10^{10} years	

(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
Lengthening of wavelength of light with expansion of space.	

(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 = 9.8×10^{9} years **maximum age =** 1.8×10^{10} years	

(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 Universe must be older than the stars so the young age is wrong.	

Overall banding: Medium

This candidate obtained a middle range score. Comments on the individual questions show that this mark could have easily been improved by closer reading of the questions and rather more care with longer written responses. It is not uncommon for candidates scoring at this level to perform most calculations with a degree of ease whilst producing disappointing responses to explanatory questions. This is a skill that can be improved through practice and by ensuring that there are opportunities to discuss the ideas covered in the course. Also note that the candidate did not always use answer lines when given – this indicates a rushed approach to answering the questions although there is no indication that the candidate ran out of time.